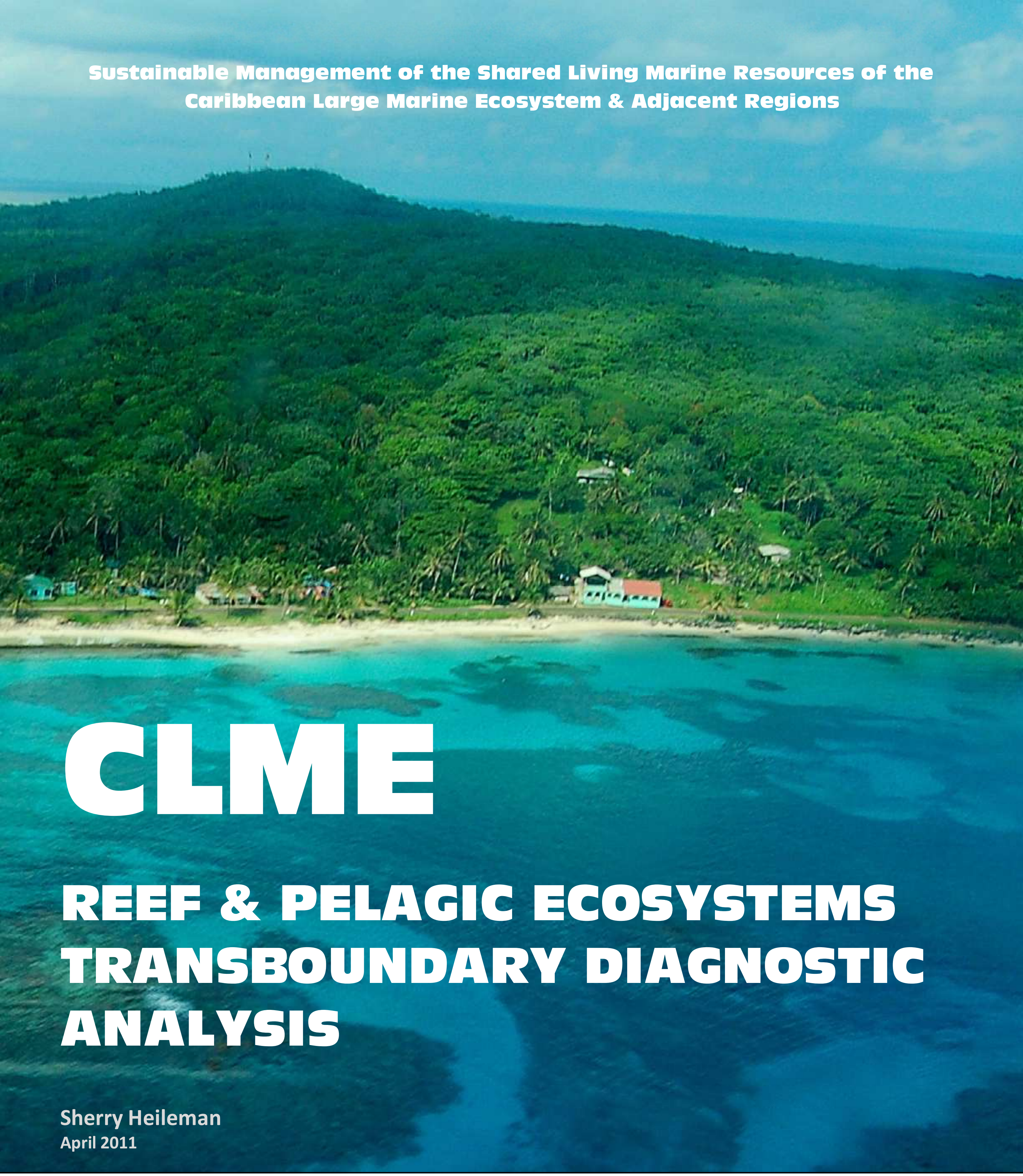

Sustainable Management of the Shared Living Marine Resources of the Caribbean Large Marine Ecosystem & Adjacent Regions

CLME

REEF & PELAGIC ECOSYSTEMS TRANSBOUNDARY DIAGNOSTIC ANALYSIS

Sherry Heileman

April 2011

Caribbean LME Project

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Caribbean LME Project

Sustainable Management of the Shared Living Marine Resources of the Caribbean Sea Large Marine Ecosystem (CLME) and Adjacent Regions

Consultancy to deliver the CLME Project Causal Chain Analysis (CCA) revision, CCA gap analysis and the update of the Reef and Pelagic Ecosystems Transboundary Diagnostic Analysis (TDA)

Prepared for

The Caribbean Large Marine Ecosystem and Adjacent Areas (CLME) Project
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By

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ACRONYMS AND ABBREVIATIONS

AGRRA	Atlantic and Gulf Rapid Reef Assessment
BOD	Biological Oxygen Demand
BPoA	Barbados Programme of Action for the Sustainable Development of SIDs
CARICOM	Caribbean Community
CBD	Convention on Biological Diversity
CCA	Causal Chain Analysis
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
CLME	Caribbean Large Marine Ecosystem
COD	Chemical Oxygen Demand
CPUE	Catch Per Unit Effort
CRFM	CARICOM Regional Fisheries Mechanism
CRW	Coral Reef Watch (NOAA)
DIN	dissolved inorganic nitrogen
EAF	Ecosystem Approach to Fisheries
EBM	Ecosystem Based Management
EEZ	Exclusive Economic Zone
ENSO	El Niño/Southern Oscillation
FAD	fish aggregating devices
FAO	Food and Agriculture Organization
FOC	Flags of Convenience
FORCE	Future of Reefs in a Changing Environment Project
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIWA	Global International Waters Assessment
GPA	Global Programme of Action for Protection of the Marine Environment from Landbased Sources
HABS	Harmful Algal Blooms
HDI	Human Development Index
HMS & SS	Highly Migratory and Straddling Stocks
IAC	Inter-American Convention for the Protection and Conservation of Sea Turtles
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Nature Conservation (World Conservation Union)
IUU	Illegal, Unreported and Unregulated (fishing)
IWCAM	Integrated Watershed and Coastal Area Management
LAC	Latin America and Caribbean
LAPE	Lesser Antilles Pelagic Ecosystem
LBA	Landbased Activities and Sources
LBA	Protocol Concerning Marine Pollution from Land-Based Sources and Activities
LME	Large Marine Ecosystem

LOSC	Law of the Sea Convention
MA	Millennium Ecosystem Assessment
MAR	MesoAmerican Reef
MEA	Multinational Environmental Agreements
MPA	Marine Protected Area
MSY	Maximum Sustainable Yield
MTI	Marine Trophic Index
NTR	No-Take Reserve
OSPESCA	Organización del Sector Pesquero y Acuícola del Istmo Centroamericano
PAHO	Pan American Health Organization
POPS	Persistent Organic Pollutants
SAP	Strategic Action Programme
SCRS	Standing Committee on Research and Statistics (ICCAT)
SIDS	Small Island Developing States
SPAW	Protocol Concerning Specially Protected Areas and Wildlife in the Wider Caribbean Region
SSP	Stock Status Plot
SST	Sea Surface Temperatures
STAG	Stakeholder Advisory Group
TDA	Transboundary Diagnostic Analysis
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids
TTT	Technical Task Team
UBC	University of British Columbia
UNGA	UN General Assembly
WCR	Wider Caribbean Region
WECAFC	Western Central Atlantic Fisheries Commission
WRI	World Resources Institute

EXECUTIVE SUMMARY

✓ Transboundary diagnostic analysis

An important component of International Waters projects of the Global Environment Facility (GEF) is a transboundary diagnostic analysis (TDA), which is an objective, non-negotiated assessment using best available verified scientific information to examine the state of the environment and the root causes for its degradation. The TDA provides the technical and scientific basis for the logical development of a Strategic Action Programme (SAP) that is based on a reasoned, holistic and multisectoral consideration of the problems associated with the state of and threats to transboundary water systems and resources. The SAP embodies specific actions (policy, legal, institutional reforms or investments) that can be adopted nationally, usually within a harmonized multinational context, to address the major priority transboundary concern(s), and over the longer term restore or protect a specific body of water or transboundary ecosystem.

Development of the TDA is also a valuable means for multilateral exchanges of perspectives and stakeholder consultation as a precursor to the eventual formulation of a SAP. The initial TDA for the Caribbean Sea Large Marine Ecosystem (CLME) consisted of thematic reports developed in 2007 during the project preparatory phase in three sub-regions (Insular Caribbean, Central/South America and Guianas/Brazil). The analysis included a preliminary causal chain analysis (CCA), which traces the cause-effect pathways of a problem from the environmental and socioeconomic impacts back to its root causes. Its purpose is to identify the most important causes of priority problems in international waters in order to target them by appropriate policy measures for remediation or mitigation. By understanding the linkages between issues affecting the transboundary aquatic environment and their causes, stakeholders and decision makers will be better placed to support sustainable and cost-effective interventions.

Following extensive technical discussions at the CLME TDA and Strategic Action Programme (SAP) Training Workshop held in Cartagena, 25-30 January 2010, the members of the TDA Technical Task Team (TTT) and the Stakeholder Advisory Group (STAG) agreed that the updated TDAs should be based on three specific fishery ecosystems (rather than geographical sub-regions): continental shelf, reef, and pelagic ecosystems. Participants at this workshop confirmed that the three issues previously identified were still of priority in the CLME, and developed preliminary CCA statements for these issues in each of the three fisheries ecosystems.

The TDAs presented in this report cover the reef and pelagic ecosystems. The CCA statements developed by the TTT in January 2010 were also validated using the Global International Waters Assessment (GIWA) methodology and incorporated in the TDAs. Preliminary drafts of the TDAs were presented to the Technical Task Team (TTT) at its two meetings in September and November 2010 as well as at the CLME Steering Committee meeting in November 2010, both in Panama. Feedback received was incorporated in the TDAs. An expanded draft, which also included a request for information, was circulated to the participating countries in December 2010, two of whom provided comments and relevant information. A brief questionnaire was also circulated to the countries in February 2011 with the aim of addressing existing data and information gaps at the country level. Comprehensive comments were also provided by the CLME Project Coordinating Unit.

A comparison between the previous thematic reports for the Insular Caribbean and Central/South America is included at the beginning of this report. In general, the updated TDAs contain considerably more data and information on the three priority issues and on the socio-economic background of the region, and greater in-depth analyses. Since the preparation of the thematic reports in 2007, the body of relevant information on the CLME grew significantly and some of this is included in the current analysis. These include updates of some major publications that were used in the previous reports. Data and information availability was problematic in some cases, including in a disaggregated form for the reef and pelagic ecosystems separately.

✓ The CLME region

The CLME covers an area of about 3 million km^2, making it the second largest sea in the world. A number of unique features make the CLME of special global and regional significance. It is bordered by 22 independent states and 17 overseas dependent territories. Twenty-two of the entities are Small Island Developing States (SIDS), the largest number of SIDS in any of the world's LMEs. Different historical and cultural backgrounds make the CLME the most geopolitically diverse and complex region in the world. The CLME provides a wide range of ecosystem services on which the wellbeing of its coastal communities is highly dependent.

Most of the Caribbean economies are heavily reliant on their marine environment and living marine resources to achieve their sustainable development goals. The importance of the Caribbean Sea for sustainable development of the bordering countries is recognized in a number of international (UN) declarations. Further, the Caribbean Sea will be designated a "Special Area" under provisions of the International Convention for the Prevention of Pollution from Ships (MARPOL)", from 1st May 2011. The Caribbean Sea has been ranked by expert consensus as having the highest priority for conservation of any marine eco-region in the whole of Latin America and the Caribbean.

✓ Climate and oceanography

The region is dominated by a tropical climate, with distinct wet (roughly June – November) and dry seasons (December – May), moderate air temperature ranges, and persistent trade winds. The wet season is associated with a continuous series of tropical waves, some developing into depressions, tropical storms, and hurricanes. A distinctive hurricane season extends from June to November. Water flows into the Caribbean Sea from the Atlantic Ocean, and then continues westward towards the Gulf of Mexico as the Caribbean Current, the main surface circulation in the Caribbean Sea. Oceanic fronts in the region are generated by coastal wind-induced upwelling off Venezuela and Colombia.

A dominant feature of the CLME is the massive quantities of fresh water and sediments entering from three major South American rivers (Amazon, Orinoco, and Magdalena Rivers). River runoff, which is strongly seasonal, with the strongest flow occurring between June and November, exerts significant influence on the ecology of the Caribbean Sea. The ocean circulation patterns in the Caribbean Sea and the transboundary nature of its living marine resources give rise to significant linkages among the region's coastal and marine areas and living marine resources.

✓ Key ecological features

On the whole, the Caribbean Sea is mostly comprised of clear, nutrient-poor waters. Nonetheless, there is considerable spatial and seasonal heterogeneity in productivity throughout the CLME, brought about by interaction of open ocean waters, coastal and ocean processes, and riverine flows. High productivity is found in a range of coastal habitats such as coral reefs, mangrove forests, and seagrass beds as well as in areas of oceanic fronts and upwellings. An immense diversity of marine fish and invertebrates from inshore and oceanic areas form the basis of important fisheries, while coral reefs contribute to the region's lucrative tourism industry.

Important ecological and biodiversity features include:

- Two biodiversity hotspots – Insular Caribbean and MesoAmerican hotspots – the former containing high marine endemicity.
- The longest barrier reef in the Western Hemisphere –the MesoAmerican Reef system.
- At least 12,046 species are reported to occur (Census of Marine Life).
- Number of species in the shallow marine environment: 62 species scleractinian coral, 4 mangroves, 7 seagrasses, 117 sponges, 633 molluscs, 378 bivalves, 77 stomatopods, 148 echinoderms, over 1,400 fish, 76 sharks, 45 shrimp, 30 cetaceans, 1 sirenia, and 23 seabird species.
- About 45% of the fish species and about 25% of the coral species are considered Caribbean endemics.
- About 118 known marine invasive species.
- Six species of marine turtles and 34 of marine mammals, several of which are endangered.
- Annual aggregation of the world's biggest fish – the whale shark (Rhincodon typus) and the largest population of this species documented in the world.
- The largest green turtle nesting colonies in the Western Hemisphere and one of the two largest remaining in the world found at Tortuguero, Costa Rica.
- Home to a large number of species of North American migratory birds during the boreal winter months.
- A number of threatened and endangered species.

✓ Socio-economic background

The CLME countries range from the most to the least developed, and includes the poorest country in the western hemisphere as well as a number of SIDs. The latter possess certain peculiarities that make their economies and environment very vulnerable to external perturbations. Caribbean countries are considered middle- and high-income, except Haiti, which is classified as low-income. High levels of economic growth mask persistent, and in some cases, increasing poverty. About 25% of the Caribbean population can be considered as poor, with more women than men living in poverty. Other socio-economic indicators are given for the countries. Latin America and the Caribbean is the most urbanized region in the developing world, with much of the urban population living in the coastal zone. The CLME countries have a high degree of vulnerability to climate change and associated phenomena. In the last decade, the region suffered from several major natural disasters that caused significant damage and a great number of fatalities.

The Caribbean Sea and its living resources are intensively used for fishing, tourism, shipping, and petroleum exploitation. It is noted for its maritime industry, with the Panama Canal the world's leading maritime hub. Tourism and fisheries are of considerable socio-economic importance in the region, and are heavily dependent on the ecosystem services provided by the CLME. Relative to its size, the Insular Caribbean is the most tourism-driven region in the world, with the economies of many of the islands very dependent on tourism. Although marine fisheries make only a small contribution to GDP, they represent a very important source of food, livelihoods, employment, income, and foreign exchange earnings in all the countries. In the 1970s and 1980s, many Caribbean countries embarked on large fisheries expansion programmes, including for large pelagic resources. In 2006, the value of the total fisheries landings from the CLME was more than US$500 million.

Important socio-economic features include:

- The highest number of SIDS and maritime boundaries of all the world's LMEs.
- Contains the poorest, least developed country in the western hemisphere and the most wealthy, developed country.
- Fisheries and tourism are of major socio-economic importance, and highly dependent on the ecosystem services of the CLME.
- The annual value of services provided by Caribbean coral reefs was estimated at between US$3.1 billion and US$4.6 billion, with degradation by the year 2015 potentially costing between US$350 million and US$870 million/year.
- About 5 million people are dependent on marine fisheries for their livelihoods.
- Fish protein supply per capita exceeds the world average of 4.5 g/day in 11 of the countries.
- The region's fishing fleet consists of nearly 30,000 boats (excluding Mexico).
- Marine-based tourism is the most important sector in a number of CLME countries.
- Tourism is the fastest growing sector, with almost 25 million tourists having travelled to the Caribbean during the year 2000.
- The Latin America and Caribbean region is the most urbanized region in the developing world, with 77% of its population living in cities, many of which are in the vulnerable coastal zone.
- In the Caribbean, more than 116 million people live within 100 km of the Caribbean coast and about 43 million people live on the coast within 30 km of a coral reef.
- The region is very vulnerable to natural disasters, including storms and hurricanes.

✓ Ecosystem services

The CLME provides valuable ecosystem services (benefits derived from ecosystems) to the people of the region. The Millennium Ecosystem Assessment defined four types of ecosystem services:

Provisioning services: The products people obtain from ecosystems, such as food, fuel, fiber, fresh water, and genetic resources.

Regulating services: The benefits people obtain from the regulation of ecosystem processes, including air quality maintenance, climate regulation, erosion control, regulation of human diseases, water purification, and protection from extreme events such as storms and tidal surges.

Cultural services: The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.

Supporting services: Services that are necessary for the production of all other ecosystem services, such as primary production, production of oxygen, and soil (beach) formation.

In order to derive maximum benefits from these ecosystems on a sustainable basis, their overall ecological health must be maintained. Yet, these valuable systems are under growing threats from human activities and natural pressures such as global warming and climate variability. Marine ecosystems and their living resources continue to be treated in a fragmented manner, with individual habitats or fish stocks assessed and managed separately, with little consideration to preserving the overall health of the ecosystem. Because of the high connectivity among the various components of the CLME, it is imperative that this ecosystem is managed in its entirety, as a single, integrated system. The TDAs show how human and natural pressures have caused severe and widespread deterioration of the CLME. The overall health of this ecosystem has been severely impaired, which compromises its ability to continue to provide the ecosystem services on which the wellbeing and socio-economic development of millions of people in the region depends.

✓ Reef ecosystem

In the CLME TDA, the reef ecosystem is considered to include shallow water coral reefs as well as mangroves, seagrass beds, lagoons, estuaries and beaches, and coral banks and rocky outcrops in deep waters that support valuable fisheries resources. There is high connectivity among these different components, making it necessary to consider them as one large, interdependent marine ecosystem with shared biodiversity. The coral reef-mangrove-seagrass complex is one of the most biologically diverse and productive systems in the world. They serve as feeding and nursery grounds for fish and invertebrate species with transboundary distribution. The annual value of services provided by Caribbean coral reefs has been estimated at between US$3.1 billion and US$4.6 billion, with degradation by 2015 potentially costing between US$350 million and US$870 million per year.

These coastal habitats have important transboundary significance in that they harbour high genetic and biological diversity and serve as feeding and nursery grounds for fish and invertebrate species with transboundary distribution either as larvae or adults. Mangroves and seagrass are important carbon sinks, which is pertinent to the issue of concentration of greenhouse gases and global warming. Coral reefs contribute to the region’s tourism industry and support important fisheries throughout the region. Among the major reef associated species that are exploited in the CLME are spiny lobster, queen conch, snappers and groupers, in addition to an immense variety of other fish species.

✓ Pelagic ecosystem

The pelagic ecosystem is considered as the epipelagic zone of the ocean, extending from the surface to a depth of about 200m. It can be characterized by differences in abiotic and biotic factors and the presence of ocean fronts. Areas of high productivity within the pelagic zone include coastal upwelling and ocean fronts.

The pelagic realm provides important habitats for adult and other life history stages of living marine resources as well as lower trophic levels (phyto and zooplankton) that are important in ocean food webs. The fish communities in the pelagic system include a wide range of small coastal pelagic species that are important components of the pelagic food web as well as large pelagic species such as mackerels, tunas, sharks and billfishes.

For the purposes of the pelagic ecosystem TDA, the focus is on the large pelagic fish stocks, which comprise two groups: large coastal pelagics (e.g. small tunas and mackerels); and the more widely distributed and migratory large oceanic species (e.g. yellowfin and skipjack tunas, swordfish and marlins). Many of these fisheries resources are transboundary as they are shared between countries with some even extending into international waters, and the likely wide dispersal of larval stages across EEZs. Over the last 15 - 20 years, the region's capacity for exploiting large pelagic resources has expanded considerably, especially through the development of longlining for oceanic pelagic species. The countries with well-developed fisheries for large pelagic resources include Barbados, Grenada, St. Lucia, Trinidad and Tobago, and Venezuela.

✓ Priority transboundary problems

The three priority transboundary problems that affect the health and productivity of both the reef and pelagic ecosystems of the CLME have been identified as: unsustainable exploitation of fish and other living resources, habitat degradation and community modification, and pollution. These issues are inter-related and interact to affect the CLME reef and pelagic systems and their living resources. In addition, climate change is a cross-cutting issue with already severe impacts on the CLME and its living resources.

✓ Unsustainable exploitation of fish and other living resources

The major environmental impacts of unsustainable exploitation include reduced abundance of stocks (as evident in decreasing total catches and catch per unit effort and collapsed stocks), change in trophic structure of fish populations with a trend towards small, low trophic level species, threats to biodiversity, and degradation of habitats.

In general, all the major reef fisheries resources, including lobster, conch, snappers and groupers have been overfished, with decline in landings in recent years. Queen conch has been overexploited to the point where it warranted international action by CITES and overharvesting of marine turtles and their egg has contributed to their endangered status. Of particular concern is the overfishing of spawning aggregations of reef fish, many populations of which have been extirpated in the region. Certain reef fish species are listed by IUCN as critically endangered, threatened or vulnerable. In 2006, about 75% of the commercially exploited reef fish stocks were either exploited (40%), overexploited (about 20%) or had collapsed (nearly 20%).

Overfishing threatens more than 70% of Caribbean reefs. Unsustainable exploitation has led to deterioration of reef condition in the Caribbean, as seen in the overgrowth of reefs by algae when the abundance of herbivorous fish (such as the Caribbean parrotfish) is reduced through overexploitation. This is of particular concern in areas where reefs have already been affected by the mass mortality of the spiny sea urchin, another important herbivore on coral reef.

Large pelagic resources are also being exploited beyond sustainable levels, including dolphinfish, wahoo, blue and white marlin, sailfish and yellowfin tuna. The number of overexploited and collapsed stocks of large pelagic resources increased markedly from the late 1970s, with the proportion of collapsed stocks reaching almost 40% in 2006. In this year, about 60% of the pelagic stocks were overexploited and collapsed and about 10% rebuilding. These trends confirm the widespread reports of overexploited and collapsed stocks in the CLME, and are consistent with the unregulated expansion of fishing in previous decades. The increasing use of conventional food fish such as flyingfish for bait in the large pelagic fisheries is an emerging issue that needs to be closely monitored.

An issue of concern in the large pelagic fisheries is the high level of bycatch, including threatened, endangered and /or protected species such as marine mammals, marine turtles and sharks as well as seabirds. The practice of Illegal, Unreported, and Unregulated fishing is an enormous problem with respect to the pelagic resources as most countries do not have the capacity for surveillance and enforcement in their respective EEZs. Related to this is the issue of Flags of Convenience (FOC), which promotes unsustainable fishing. An analysis of information available from the Lloyd's Register of Ships between 1999 and 2005 showed that four CLME countries have consistently topped the list of FOC countries with the largest number of large-scale fishing vessels (>24m) registered to fly their flag.

One of the ecosystem impacts of overfishing is the change in trophic structure of fish communities, which is manifested by a decline in the abundance of large predatory fishes and a shift to smaller, low-value species. This phenomenon is evident in both the reef and pelagic ecosystems, which indicates that fishing has impaired ecosystem functioning.

Unsustainable exploitation has severe socio-economic consequences, including reduced food security as well as reduced livelihood, income and employment in the region from both fishing and tourism. This is of particular concern in coastal areas with high poverty levels. Reduction in the abundance of pelagic fish could also have negative consequences for tourism and recreational fishing, which is growing in the region, and lead to conflicts between fishers and even countries that exploit the same stocks.

✓ Habitat degradation and community modification

The major environmental impacts of habitat degradation and community modification include loss of ecosystem structure and function; reduction/loss of biodiversity; and reduction in fisheries productivity. A previous assessment revealed that nearly two-thirds of the region's coral reefs were threatened by human activities, coral diseases and bleaching. An update of this assessment showed an increase in this proportion to more than 75%, with more than 30% in the high and very high threat categories. Increasing sea surface temperatures are causing widespread damage and death to corals in the Caribbean Sea. Drastic changes to Caribbean reefs are being caused by overfishing of herbivores, which promotes the overgrowth of corals by algae and slows reef recovery from bleaching. Degradation of coral reefs reduces their resilience to other stressors, particularly climate change. The red lion fish, a recently introduced invasive alien species on Caribbean reefs, has the potential to devastate reef communities.

The architectural complexity of Caribbean reefs has declined with the near disappearance of the most complex reefs over the last 40 years. This is likely to have serious consequences for reef biodiversity, ecosystem functioning and associated ecosystem services. Staghorn and elkhorn corals are listed as Critically Endangered on the IUCN Red List, because of population reductions exceeding 80%, in particular due to the effects of disease as well as climate change and human-related factors. The Mesoamerican Reef has experienced a 20% decline in health from 2006 to 2009. Deep water reefs and banks are also being impacted, including by fishing activities and petroleum exploitation. Mangroves and seagrass beds are also fast disappearing in the region because of pollution and conversion to coastal development and aquaculture. Globally, the highest proportion of threatened mangrove species is found along the Atlantic (and Pacific) coasts of Central America. Loss of adjacent mangrove and seagrass beds causes changes in reef fish communities through loss of connectivity. Extraction of sand for construction from beaches and dunes has led to severe damage of these areas in some countries.

Previous assessments in the CLME region have focused on degradation of coastal habitats such as coral reefs, mangroves, seagrass beds and beaches, with little focus on pelagic habitats. Degradation of the pelagic ecosystem can occur through large-scale processes such as climate change and ocean acidification as well as localized pollution from a number of substances. Changing climate conditions can influence ocean currents and processes, which could have severe consequences for pelagic living resources as well as for the reef system through impacts on pelagic larval survival and transport.

Habitat degradation and loss reduces the production of ecosystem services. In addition to the impacts on fisheries and tourism and associated socio-economic consequences, loss of reef habitats diminishes their coastal protection function. Other economic impacts of habitat and community impacts are degraded land due to erosion, increased costs of addressing coastal erosion and controlling invasive species and restoration of modified ecosystems. Habitat degradation also results in loss of aesthetic, educational and scientific values and of cultural heritage.

✓ Pollution

The transboundary significance of this issue arises both from the transboundary origin of pollutants and impacts on transboundary living marine resources. Data and information on pollution for the reef and pelagic ecosystems were often not available separately. For the reef ecosystem, analysis of pollution focuses on nutrients and sediments, while these and other pollutants are included for the pelagic ecosystem. Elevated sediment and nutrient loads, particularly from agricultural sources, are among the major threats to CLME reefs. This underscores the need for countries to implement the LBA Protocol of the Cartagena Convention and other measures such as IWCAM. Over 250 million tonnes of sediments and nearly 850,000 tonnes of nutrients (nitrogen and phosphorus) are discharged each year to the Caribbean Sea (not including inputs from the Orinoco River). Elevated nutrient levels cause eutrophication, which can lead to harmful algal blooms, hypoxia and fish kills, which seem to be increasing in the region. Pollutants from areas outside the CLME is also of concern, as these reach the Caribbean through river run off and ocean currents (e.g. from the Orinoco and Amazon Rivers) and atmospheric transport (from North Africa, where countries apply large amounts of pesticides, including those banned in the Caribbean and USA).

In addition to sediments and nutrients, a number of other substances cause pollution of the pelagic ecosystem. Of great concern is hydrocarbon pollution, for which there is a high risk due to the heavy shipping traffic and petroleum industry in the region. A total movement of 103,970 ships and averages of 8,664 ships per month and 285 ships per day have been estimated in the Caribbean Sea. In 2005, six million tonnes of ballast water were poured into the Caribbean Sea, of which 84% came from international shipping. About 7 million barrels of oil are discharged annually from tank washings. Other concerns are untreated sewage, agricultural pesticides and industrial wastes containing heavy metals and other hazardous substances, as well as solid waste. A number of pollution hotspots are found throughout the region.

The major environmental impacts of pollution of the pelagic ecosystem include deterioration of environmental quality, degradation of habitats and threats to living marine resources. Contaminants such as mercury can accumulate in higher levels of marine food chains, which is of concern in large pelagic fish species that are among the top predators in the ocean.

Pollution poses a serious risk to human health both through direct physical contact and consumption of contaminated seafood. It has also diminished the aesthetic value of some areas, impacting on recreational activities and reducing revenue from tourism. The economic cost of addressing pollution (e.g. clean up of oil spills, adoption of new technologies in industry, construction and maintenance of sewage treatment plants) and of medical treatment of pollution-related illnesses could be very significant.

✓ Causal chain analysis

A causal chain is a series of statements that link the causes of a problem with its effects. It identifies the following causes:

Immediate causes: The physical, biological or chemical variables that have a direct impact on an issue; for example, enhanced nutrient inputs in the case of eutrophication.

Sector activities: Include two components- the activities in the different economic sectors that provoke the immediate cause (e.g. in the agricultural sector, the excessive application of certain kinds of pesticides) and the decisions made by firms, farmers, fishermen, households, government officials or politicians (socio-economic agents in general) that directly or indirectly produce the negative impact (e.g. farmers´ decision to use a highly persistent pesticide).

Underlying causes: Includes two components - Resource uses and practices; and Social, economic, legal and political causes.

Root causes: The key factors, trends, processes or institutions that influence a situation, issue, or decision that propel the system forward, and determine a scenario's outcome (e.g. governance and culture).

✓ CCA Unsustainable exploitation

The major sectors are fishing, trade and tourism.

Immediate causes: Catches beyond sustainable levels, including immature and/or spawning individuals; Bycatch and discards.

Underlying causes: Open access nature of fisheries; Fishing overcapacity; Destructive fishing methods; Illegal, Unregulated and Unreported catches; Deficiencies in institutional, policy and legal frameworks; Inadequate institutional, human and technical capacity; Inadequate enforcement, monitoring and surveillance; Perverse incentives; Improvements in technology; Inadequate institutional, human and technical capacity; Inadequate financial resources; and Inadequate data and information.

Root causes: Poor Governance; Unsustainable development models; Population and cultural pressures; Inadequate knowledge and low public awareness; Lack of alternative food source and employment; High dependence on fish for income and export earnings.

✓ CCA habitat degradation

All major sectors contribute to this issue.

Immediate causes: Physical alteration, damage and destruction through mechanical means, including removal and burial; Pollution (chemical, microbial, sediments, nutrients); Overfishing; Invasive species; Diseases; Global warming and climate change (coral bleaching, acidification, sea level rise, storms and hurricanes).

Underlying causes: Demography and urbanization; Increasing demand for food production, employment and income; Land use changes and poor agricultural practices; poorly planned coastal development; Harmful tourism practices; Limited integrated watershed and coastal area management; Limited human and institutional capacity; Harmful subsidies and lack of incentives for sustainable practices; Intensive maritime and petroleum activities; Inadequate waste management; Weakly developed and enforced legislation; Inadequate institutional capacities; and limited financial resources.

Root causes: Poor governance; Weak and ineffective legal and institutional frameworks; Trade and external dependency; Lack of economic valuation of ecosystems and their services; Limited knowledge and public awareness; Population and cultural pressures.

✓ CCA Pollution

All major sectors contribute to pollution

Immediate causes: Nutrients, sediments, sewage, hydrocarbons, agricultural chemicals, heavy metals, POPs, solid waste.

Underlying causes: Demography and urbanization, Inadequate waste management and disposal, Improper land use and poor agricultural practices, Increasing demand for food production, employment and income, Poorly planned coastal development, Harmful tourism practices, Intensive maritime and petroleum activities.

Root causes: Poor governance; Weak and ineffective legal and institutional frameworks; Inadequate environmental quality standards and legislation; Inadequate data and information; Limited financial and human resources; Low awareness of the value of the environment; and illiteracy.

✓ Future interventions

There is a wide range of global and regional legal instruments, agreements, arrangements and action plans that are directly relevant to the management of the transboundary living marine resources of the Caribbean Sea. There should be greater focus on improved implementation of these instruments and frameworks. Actions at the national level need to be undertaken within a broader multi-scale governance framework (from local to regional and global), depending on the geographical distribution of the transboundary resources or the scale of the issue. Addressing the transboundary issues should be incorporated within a collaborative and harmonized regional framework or mechanism. Developing these multi-scale frameworks and their effective functioning must be underpinned by credible data and information at the appropriate scale. Addressing transboundary issues will also need further strengthening of human capacity.

EBM/EAF approaches are increasingly being accepted as the most appropriate frameworks to manage living marine resources, including shared resources. The nature of the CLME and its shared resources as well as its shared and common problems makes it an ideal candidate for EBM/EAF approaches, which puts emphasis on, among other aspects, maintaining the overall health of the ecosystem in order to maintain the production of ecosystem services as well as on the role of humans as a vital part of the ecosystem. Examples of specific interventions for each of the three priority trasboundary issues are presented.

1. INTRODUCTION

1.1. Reorientation and preparation of the Reef and Pelagic Ecosystems TDAs

During the preparatory phase of the Caribbean Large Marine Ecosystem (CLME) project, a preliminary Transboundary Diagnostic Analysis (TDA) was developed for three sub-regions (Insular Caribbean, Central/South America and Guianas/Brazil) in 2007. These were referred to as thematic reports, which were subsequently used to produce an integrated regional TDA. The priority transboundary issues of the CLME were identified, in consultations with major stakeholders, as unsustainable exploitation of living marine resources, habitat degradation and community modification, and pollution. Each of the thematic reports analysed the environmental and socio-economic impacts of these priority transboundary issues in the respective sub-regions. Further, for each issue a preliminary causal chain analysis (CCA) of the immediate, underlying and root causes of these problems was developed, knowledge gaps identified, and interventions proposed for addressing the issues.

During the current full-size project, the focus of the sub-regional TDAs was reoriented. Following extensive technical discussions at the CLME TDA and Strategic Action Programme (SAP) Training Workshop held in Cartagena, 25-30 January 2010, the members of the TDA Technical Task Team (TTT) and the Stakeholder Advisory Group (STAG) agreed that the updated TDA should be based on fishery ecosystems (rather than geographical sub-regions), consistent with the overall goal[1] of the project. Three specific ecosystems (continental shelf, reef and pelagic ecosystems) were agreed as the new focus of the revised TDAs. At this workshop, the three thematic reports were also reviewed and the CCAs for the three fisheries ecosystems were discussed. Participants confirmed that the three issues previously identified were still the three priority issues confronting the CLME, and developed preliminary CCA statements for these issues in each of the three fisheries ecosystems.

This current report presents the TDAs for the CLME reef and pelagic fisheries ecosystems. These TDAs were elaborated on the basis of the previous sub-regional thematic reports for the Insular Caribbean and Central/South America as well as on additional data and information. Preliminary drafts of the reef and pelagic TDAs were presented to the TTT at its two meetings in September and November 2010 as well as at the CLME Steering Committee meeting in November 2010, both in Panama. Feedback received was incorporated in the TDAs. An expanded draft, which also included a request for information from the countries in the form of a list of questions, was circulated to the participating countries in December 2010, two of whom provided comments and relevant information from their respective countries. A brief questionnaire was also circulated to the countries in February 2011 with the aim of obtaining data and information from the countries. The response from the countries was poor, and country level information was obtained from a number of other sources and integrated to provide a regional overview of the CLME. Comprehensive comments were also provided by the CLME Project Coordinating Unit.

[1] The goal of the CLME project is the sustainable provision of goods and services of the shared living marine resources in the Wider Caribbean through robust co-operative governance

The CCA statements developed by the TTT in January 2010 were validated and prioritized using the Global International Waters Assessment (GIWA) methodology and incorporated in the TDAs.

1.2. Differences between the previous thematic reports and current TDAs

The present TDAs for the reef and pelagic ecosystems are different in many respects from the previous thematic reports for the Insular Caribbean and Central/South America sub-regions. The current reports are full TDAs that cover the reef and pelagic ecosystems of the entire CLME region, in contrast to the previous reports that were based on two sub-regions. Since the preparation of the thematic reports in 2007, the large body of relevant information on the CLME continued to grow and some of this is included in the current analysis. These include updates of some major publications that were used in the previous reports. The current TDAs are very data rich and provide comprehensive analyses of the three priority issues, backed up with recent socio-economics, ecological and environmental data and information. A number of the information gaps identified in the 2007 reports were addressed in the current report as information became available. A summary of the major differences between the 2007 reports and the current 2011 TDAs is given in Annex 1.

2. BACKGROUND

2.1. Global and regional significance of the CLME

The CLME is a semi-enclosed tropical sea bounded to the north by the Bahamas and the Florida Keys, to the west and south by Central and South America, and to the east by the Lesser and Greater Antilles Island chain (Figure 1). It is bordered by the Gulf of Mexico LME to the north and the North Brazil Shelf LME to the south. This distinct ecological region covers an area of about 3.3 million km^2 (Sea Around Us Project 2010), making it the second largest sea in the world. The CLME region is also referred to as the Wider Caribbean Region (WCR), which is a part of the Greater Caribbean that also encompasses the Gulf of Mexico and Guiana region of the Atlantic Ocean.

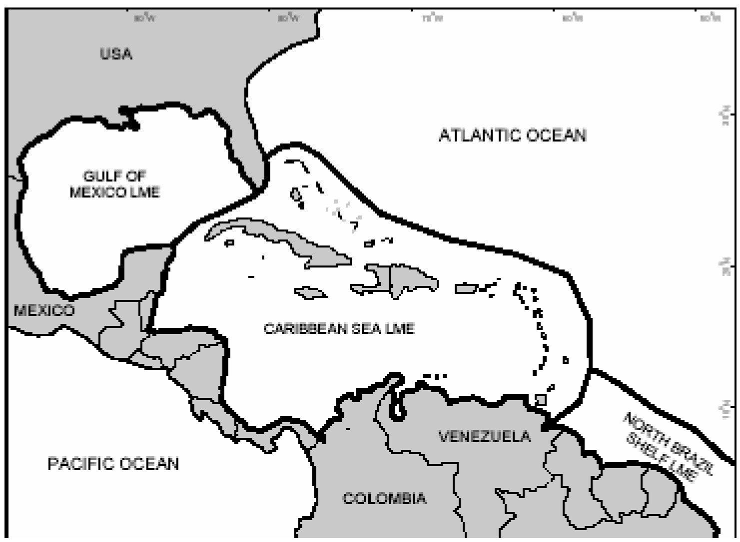


Figure 1. Map of the CLME

A number of unique features make the CLME of special global and regional significance. The region is the most geopolitically diverse and complex in the world. Bordered by 22 independent states and 17 dependent territories (USA, UK, France, and the Netherlands) means that the CLME has the highest number of maritime boundaries of any other LME. This presents a considerable challenge for the effective management of the region’s living marine resources, especially as many of them are transboundary. These countries and territories range from the largest to the smallest in the world, and from the most developed – USA and European countries– to the least developed –Haiti (Table 1). Another unique feature of the CLME is its 22 Small Island Developing States[2] (SIDS), the largest number of SIDS in any of the world’s LMEs. A number of the continental countries also possess islands in the Caribbean Sea, such as Colombia, Mexico, and Venezuela.

[2] Included in the UN list of SIDS

Table 1. States and Overseas Dependent Territories of the CLME

Continental States	Independent Island States	Overseas dependent territories (metropolitan countries)
*Belize	*Antigua & Barbuda	*Anguilla (U.K.)
Colombia	*Bahamas	*Aruba (Netherlands)
Costa Rica	*Barbados	*British Virgin Islands (U.K.)
Guatemala	*Cuba	Cayman Islands (U.K.)
Honduras	*Curaçao[1]	Guadeloupe (France)
Panama	*Dominica	*Montserrat (U.K.)
Mexico	*Dominican Republic	Martinique (France)
Nicaragua	*Grenada	*Puerto Rico (U.S.A.)
Venezuela *(Bolivarian Republic of)*	*Haiti	*Netherlands Antilles (Netherlands): Bonaire, St. Eustatius, Saba
	*Jamaica	St. Barthélemy (France)
	*St. Kitts & Nevis	St. Martin (France)
	*St. Lucia	Turks and Caicos (U.K.)
	*St. Maarten[1]	*U.S. Virgin Islands (U.S.A.)
	*St. Vincent & the Grenadines	
	*Trinidad & Tobago	

[1]Previously Dutch territories, became independent on 10 October 2010
*SIDS

The importance of the Caribbean Sea for sustainable development is recognized in a number of international (UN) declarations. Among these are:

- Resolution 54/225 "Promoting an integrated management approach to the Caribbean Sea area in the context of sustainable development", which was adopted by the 54th Session of the UN General Assembly (UNGA) in February 2000. This Resolution encourages the further development of an "integrated management approach" to the Caribbean Sea area in the context of sustainable development, incorporating environmental, economic, social, legal and institutional elements, and called upon the international community and the UN System to support efforts to develop and implement such an approach;
- Resolution 57/261 "Promoting an integrated management approach to the Caribbean Sea area in the context of sustainable development", adopted by the UNGA on 20 December 2003;
- Resolution 63/214 "Towards the sustainable development of the Caribbean Sea for present and future generations", adopted in December 2006 in which the UNGA called on the UN system and the international community to assist, as appropriate, Caribbean countries and their regional organizations in their efforts to ensure the protection and sustainable management of the Caribbean Sea;

- Barbados Programme of Action for the Sustainable Development of SIDS (BPoA), which resulted from the UN Global Conference on the Sustainable Development of SIDS held in Barbados in 1994. This is accompanied by the Barbados Declaration, a statement of political will underpinning the agreements contained in the BPoA, which identifies actions required at the national, regional, and international levels for sustainable development in these countries and for reducing their vulnerability;
- Cartagena Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region, which was adopted in 1983. Unique to the region, the Cartagena Convention and its three protocols (Protocol Concerning Cooperation in Combating Oil Spills in the Wider Caribbean Region – Oil Spills Protocol; Protocol Concerning Specially Protected Areas and Wildlife in the Wider Caribbean Region – SPAW Protocol; and Protocol Concerning Marine Pollution from Land-Based Sources and Activities – LBA Protocol) constitute the first regional framework convention for the protection of the region's marine and coastal areas and wildlife.

A regional initiative is ongoing to have the Caribbean Sea declared by the UNGA as a 'Special area in the context of sustainable development'. The Caribbean Sea Commission was established by the Association of Caribbean States in 2006 to support this initiative and to promote coordinated governance of the Caribbean Sea for the Wider Caribbean region. From 1st May 2011 the Caribbean Sea will be designated a "Special Area" under provisions of the International Convention for the Prevention of Pollution from Ships (MARPOL)". This means from this date the disposal of garbage and other pollutants in the Wider Caribbean Sea is strictly prohibited, except in cases where it is processed in accordance with Annex V of the Convention. This includes disposal of synthetic ropes, synthetic fishing nets, plastic garbage bags, paper products, glass, metal, bottles and food wastes, among others.

The Caribbean Sea has been critically assessed and ranked by expert consensus as having the highest priority for conservation of any marine eco-region in the whole of Latin America and the Caribbean (Sealey and Bustamante 1999). The biodiversity features of the Caribbean Sea are discussed further below. Most of the Caribbean economies show a high dependence on the ecosystem services provided by marine ecosystems to achieve their sustainable development goals. In turn, the functioning of the Caribbean Sea ecosystem and the sustained delivery of its services are heavily reliant on the condition of coastal habitats (coral reefs, mangroves, seagrass beds and beaches) as well as of deep water habitats and of the pelagic ecosystem. All these systems are interconnected through the exchange of material and living resources. Therefore, impacts in one system could have severe consequences for the health and productivity of the other(s) and for the human communities that depend on them. Further, this has implications for the region as a whole because of the interconnectedness and transboundary nature of the environment and living resources of the CLME.

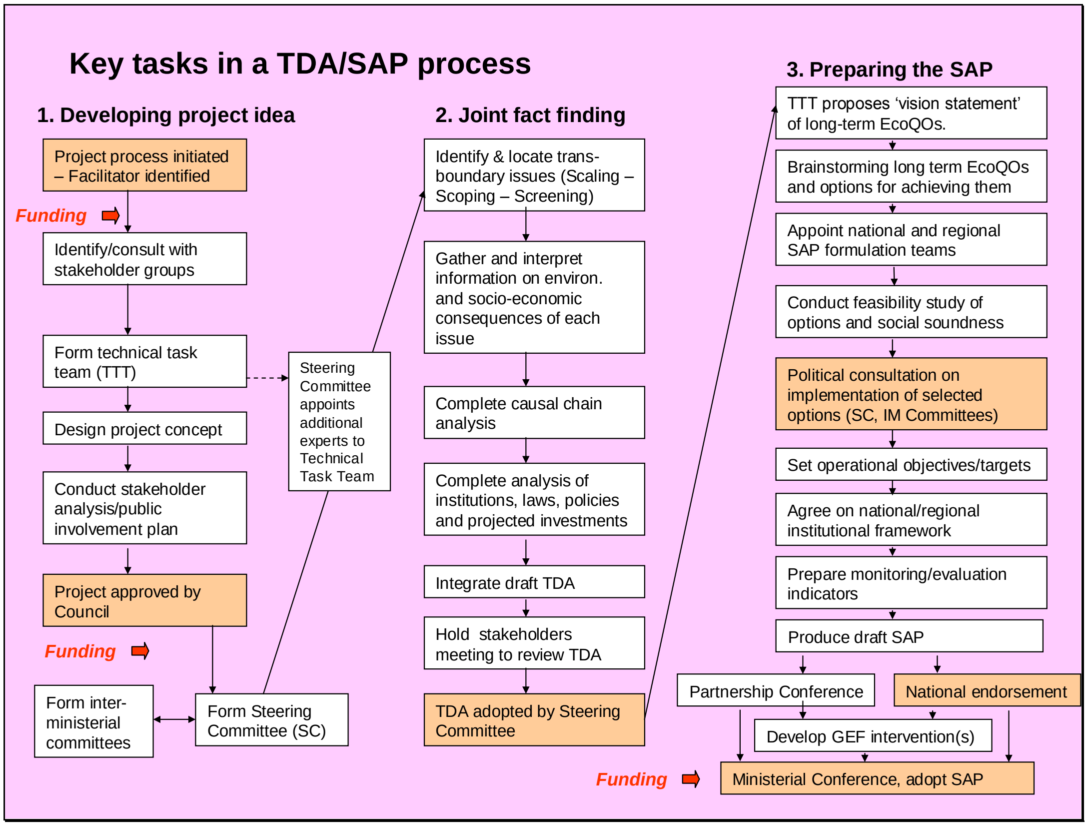
2.2. Purpose of the Transboundary Diagnostic Analysis (TDA)

A TDA is an objective, non-negotiated assessment using best available verified scientific information to examine the state of the environment and the root causes for its degradation. The TDA serves as the basis for development of a SAP with a shared vision for the CLME, and agreed priority interventions, reforms and investments. It provides the technical and scientific basis for the logical development of a SAP that is based on a reasoned, holistic and multisectoral consideration of the problems associated with the state of and threats to transboundary water systems and resources. The SAP embodies specific actions (policy, legal, institutional reforms or investments) that can be adopted nationally, usually within a harmonized multinational context, to address the major priority transboundary concern(s), and over the longer term, restore or protect a specific body of water or transboundary ecosystem.

Development of the TDA is also a valuable means for multilateral exchanges of perspectives and stakeholder consultation as a precursor to the eventual formulation of a SAP. The analysis is carried out in a cross sectoral manner, focusing on transboundary issues without ignoring national concerns and priorities. Identifying and addressing transboundary issues requires the countries to work together and share information regarding the origin and impacts of these issues.

The relationship between the TDA and SAP and key steps in the process are shown in the following schematic[3], in which the TDA process is described in Step 2.

[3] The GEF IW TDA/SAP Process*:* Notes on a proposed best practice approach. UNDP 2002



2.3. Geographic scope

2.3.1. The CLME region

The wider geographic scope of the reef and pelagic ecosystem TDA is the Caribbean Large Marine Ecosystem (CLME) and the bordering countries and territories that exploit it (Figure 1).

2.3.2. Climate and oceanography

Meteorologically, the region is dominated by a tropical climate, with distinct wet (roughly June – November) and dry seasons (December – May), moderate air temperature ranges, and persistent trade winds. Annual rainfall varies between 50 - 1,250 mm. The seasonal variations of the meteorological conditions are caused by north-south migrations of the Intertropical Convergence Zone, which is found near the Equator in winter and at about 10°N at the end of summer. During the wet season a continuous series of tropical waves move westward, some developing into depressions, tropical storms, and hurricanes. A distinctive hurricane season extends from June to November.

Water flows into the Caribbean Sea from the Atlantic Ocean mostly through the Grenada, St. Vincent, and St. Lucia Passages (Johns et al 2002) (Figure 2; Gyory et al 2006). It then continues westward as the Caribbean Current, the main surface circulation in the

Caribbean Sea. The source of the Caribbean Current is the South Equatorial, North Brazil, and Guiana Currents. The Guiana Current enters the Caribbean Sea along the northern coast of South America. Significant amounts of water is transported northwestward by the Caribbean Current, which turns sharply westward as it crosses the Cayman Basin and enters the Gulf of Mexico as a narrow boundary current, the Yucatan Current (Fratantoni 2001). The circulation in the Caribbean Sea experiences much variation in both space and time, some of it in the form of mesoscale eddies and meanders (Molinari et al 1981). The ocean circulation patterns in the Caribbean Sea and the transboundary nature of its living marine resources give rise to significant linkages among the region's coastal and marine areas and living marine resources.

Oceanic fronts in the region are generated by coastal wind-induced upwelling off Venezuela and Colombia (Belkin et al 2009). A front of about 100 km long dissects the Gulf of Venezuela along 70°40'W, likely caused by the brackish outflow from Lake Maracaibo combined with coastal upwelling. A 200 km-long front in the Gulf of Honduras peaks in winter, likely related to a salinity differential between the Gulf's apex and offshore waters caused by high precipitation in southern Belize (Heyman and Kjerfve 1999).

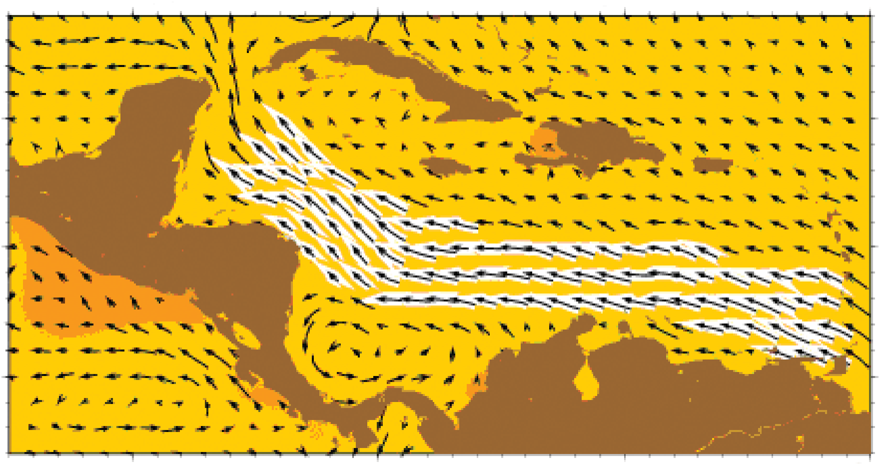


Figure 2. Caribbean Sea circulation pattern

A dominant feature of the CLME is the massive quantities of fresh water and sediments entering from three great South American river systems: the Amazon and Orinoco Rivers (which are outside of the CLME region), and the Magdalena River of Colombia. River runoff shows strong intra-annual variability, with the strongest flow occurring between June and November.

The plume of the Orinoco River, as tracked by satellite imagery, seasonally penetrates across the Caribbean Basin, potentially exerting a region-wide influence, particularly in the southern Insular Caribbean. The Amazon River is the largest point source of freshwater entering the ocean, adding an enormous surface plume that extends hundreds of kilometers to the northwest (Müller-Karger et al 1988). Although a large part of the outflow of the Amazon is taken eastward across the Atlantic, a significant quantity flows northward around the coast of the continent into the Eastern Caribbean and, together with the waters of the Orinoco, creates plumes of buoyant fresh water across wide stretches of the Caribbean Sea (Müller Karger et al 1988, 1989). In the Western Caribbean, the plume of the Magdalena River in Colombia extends north and eastward under the influence of a current known as the Colombian gyre. These rivers also contribute significant quantities of freshwater and sediments to the Caribbean Sea.

The Magdalena River is one of the most important in the world in terms of its impact on the wider environment (CARSEA 2007). It extends for 1,612 km and its basin of 257,438 km² covers 24% of the territory of Colombia and drains the Western and Central Cordilleras of the Andes. The Magdalena discharges more sediment for each square kilometer of its catchment area than any of the other large rivers along the Caribbean and Atlantic coasts of South America (560 tonnes km^{-2} $year^{-1}$). The total amount of sediment transported into the Caribbean by the Magdalena is of the same magnitude as the Amazon, Orinoco, and Paraná (Plata), which all drain into the Atlantic, and corresponds to 86% of the total sediment load of all Colombian rivers draining into the Caribbean (Restrepo and Kjerfve 2000). Sediment loads of the Magdalena River show an inter-annual oscillation well-correlated with the El Niño/Southern Oscillation (ENSO) cycle: mean daily sediment loads during El Niño years are 256 tonnes per day and during La Niña years 511 tonnes per day (Restrepo and Kjerfve 2000).

As discussed later, river outflow and the enormous quantity of sediments have significant and far-reaching impacts on the ecology of the Caribbean Sea.

2.3.3. Ecology and biodiversity

The Caribbean Sea is generally considered oligotrophic, mostly comprised of clear, nutrient-poor waters. Based on SeaWiFS global primary productivity estimates, the Caribbean Sea is considered a low productivity ecosystem (<150 g C m^{-2} yr^{-1}) (NOAA 2003). Depending on the time of year, however, the Caribbean Sea can be better defined as mesotrophic (Gilbes and Armstrong 2004). Surface waters, enriched by upwelling and by discharges from the Orinoco River, are advected northwards into the region, especially during the rainy season. The intrusion of the Orinoco River during autumn promotes large concentrations of chlorophyll *a* in the eastern Caribbean, which can be carried as far as Puerto Rico (Müller-Karger et al 1989). Moreover, strong trade winds during winter and spring generate coastal upwelling along much of the coastline of northeast Colombia and Venezuela, bringing nutrients to the surface and increasing primary production in that area (Andrade and Barton 2000, Müller-Karger and Castro 1994).

The complex interaction of open ocean waters, coastal and ocean processes, and riverine flows is reflected in geographically-varying ecosystem components that contribute to the region's rich marine ecological and biological diversity. There is a high diversity of habitat types and primary producers (e.g., coral reefs, mangroves, sea grasses, macro algae, benthic and epiphytic algae, phytoplankton). Within the CLME is found the longest barrier reef in the Western Hemisphere – the 220 km long MesoAmerican Reef (MAR) system– which extends from the Yucatan Peninsula to Honduras.

High productivity is found in these habitats, which naturally dominate the coastal margins of the CLME. These three types of habitats often exist together within a tightly-coupled ecological complex and provide important ecological services. For instance, coral reefs, mangroves, and seagrass beds function as spawning and nursery grounds for fish and invertebrates. They provide coastal protection against waves and storm surges, and coastal stabilization. Mangroves influence the productivity of coastal areas by contributing nutrients and acting as sediment traps in estuarine waters, thereby protecting coral reefs from sedimentation. Seagrass habitats are important for fishery production, and as a food source for certain threatened animal species. Areas of high productivity also include the plumes of continental rivers, as previously mentioned.

The Caribbean represents the heart of Atlantic marine diversity, with two biodiversity hotspots containing high marine endemicity: The Caribbean hotspot that encompasses the Insular Caribbean and the MesoAmerica hotspot that includes a number of nearshore and offshore islands in both the Caribbean Sea and Pacific Ocean (Figure 3). These hotspots are of international importance for their biodiversity and conservation value. The Caribbean hotspot spans 4.31 million km^2 of ocean and 0.26 million km^2 of land area, with nearly a quarter of its 60 species of corals and 1,500 species of fish being endemic. The greatest concentration of fish species in the Atlantic Ocean Basin occurs in the northern part of the hotspot in waters shared by the Bahamas, Cuba, and the US (Mittermeier et al 2000, Myers et al 2000).

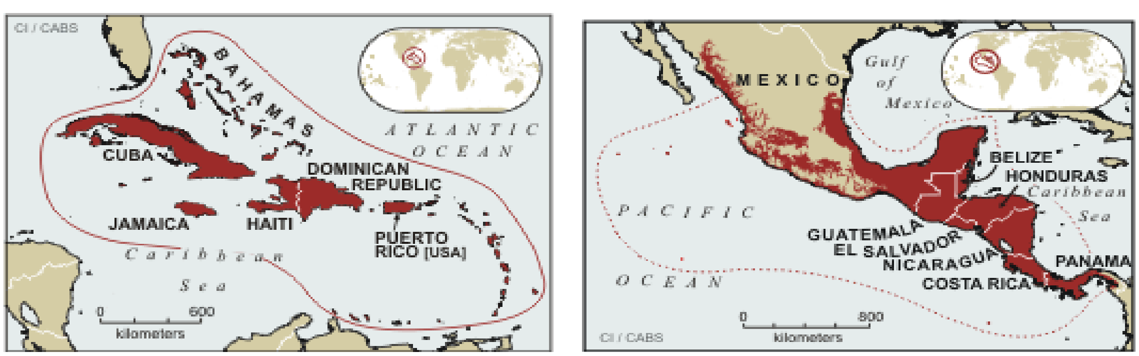


Figure 3. Caribbean and MesoAmerica biodiversity hotspots

(Conservation International, http://www.biodiversityhotspots.org/xp/Hotspots/caribbean/)

The Census of Marine Life programme in the Caribbean region found at least 12,046 species have been reported to occur in the Caribbean Sea (Miloslavich et al 2010). Estimates of the number of species in various groups are given by Huggins et al (2007) and Miloslavich et al (2010). For similar groups such as fish and mollusc, the number of species reported by these two sources is different, which could be attributed to a number of factors including methodology. The shallow marine environment contains 25 coral genera

(62 species scleractinian coral), 4 mangroves, 7 seagrasses, 117 sponges, 633 molluscs, 378 bivalves, 77 stomatopods, 148 echinoderms, over 1400 fishes, 76 sharks, 45 shrimp, 30 cetaceans, 1 sirenia, and 23 seabird species (Huggins et al 2007). By far, the most speciose taxa are Mollusc (3,032 species), Crustacea (2,916 species), and Pisces (1,336 species), which together account for about 60% of the total biota, Cnidaria (corals, jellyfish) 994 species; Porifera (sponges, ctenophores) 519 species (Miloslavich et al 2010). About 45% of the fish species are considered Caribbean endemics, whereas endemism in mollusks amounts to about 26% and in copepods to only 2% (Miloslavich et al 2010). For many taxonomic groups, the number of known species is constantly increasing as new species are described or are recorded for the first time in the region. Coastal species richness was found to be concentrated along the Antillean arc (Cuba to the southernmost Antilles) and the northern coast of South America (Venezuela – Colombia) (Miloslavich et al 2010).

The collecting effort of the Census of Marine Life in settings deeper than 200 m has been concentrated along the Mexican and Colombian continental slopes and abyssal plains, the north and south coasts of the eastern two-thirds of Cuba, the south coast of Jamaica, and the Lesser Antilles arc. Very few records exist for areas between Honduras and Panama, along the shelf north of Venezuela, and off western Cuba. The Caribbean basin deep-sea species database includes 1,530 species grouped in 12 phyla (Miloslavich et al 2010).

Caribbean marine biodiversity is under increasing threat from invasive species. A compilation of existing information revealed that a total of 118 marine invasive species were known in the region (Lopez and Krauss 2006), although Miloslavich et al (2010) reported 44 introduced species, of which few are known to be invasive. Eighteen invasive or exotic species have been reported in the Insular Caribbean (Kairo et al 2003). These include clownfish, dragonet, bamboo shark, American oyster, sea nettle, yellow-green microalga and other species (Bahamas), green mussel (Jamaica, Trinidad), and Australian spotted jellyfish (Puerto Rico). In Colombia, 16 introduced species have been identified, including the algae, corals, bivalves, crustaceans, and fishes including the recently recorded red lion fish (Gracia et al 2009). Most of these species originate from the Indo-Pacific region and the Mediterranean Sea. Two well-known marine invasive species that have significant impacts in the region are: the Indo-Pacific green mussel (*Perna viridis*), which was introduced in Trinidad in 1990 and has since spread to a number of locations throughout the Caribbean Sea (Agard et al. 1992); and the red lionfish (*Pterois volitans*), which can cause severe disruption to coral reef communities.

At least 34 species of marine mammals (31 cetacean, 2 pinnipeds, and 1 sirenian) are known to inhabit the waters of the Caribbean Sea, seasonally or year-round (UNEP-CEP/RCU 2001). The cetacean species include seven species of baleen whales and 24 species of toothed whales. Of the two pinnipeds, the West Indian monk seal (*Monachus tropicalis*) is now generally considered extinct. The West Indian manatee (*Trichechus manatus*) is native to the Caribbean Basin and is the only sirenian species in the region. Seven of the marine mammal species are classified as endangered or vulnerable by the IUCN (World Conservation Union). For many marine mammal species, Caribbean waters are primary habitat for critical activities including feeding, mating and calving.

The Caribbean is noted for the annual aggregation of the world's biggest fish – the whale shark (*Rhincodon typus*). Past surveys have shown that an estimated 1,400 whale sharks visit Gulf of Mexico and Caribbean Sea waters near Isla Holbox, Mexico each year from May to September. The presence of whale shark in this region is associated with their feeding in some of the most productive areas, which include the gyre off the coast of Utila Island, Honduras (35 individuals); the spawning aggregation site in Gladden Spit, Belize (25 individuals); and the up-welling zone in Holbox, Mexico, having the largest population of whale shark documented in the world (500 individuals recorded to date) (Arrivillaga and Windevoxhel 2008). Recently, aggregation of hundreds of whale sharks was observed east of their usual haunt, closer to Isla Mujeres in Mexico, which lasted throughout the summer. To scientists' knowledge, Isla Mujeres waters have only hosted groups of sharks in late summer, not all summer long.

The WCR includes nesting and foraging grounds, as well as important migration corridors, for six of seven extant marine turtle species: leatherback (*Dermochelys coriacea*), green (*Chelonia mydas mydas*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricate*), olive ridley (*Lepidochelys olivacea*), and kemp's ridley (*L. kempii*). All six species are included in the IUCN Red List of Threatened Species: the kemp's ridley, hawksbill and leatherback are classified as Critically Endangered, and loggerhead, green and olive ridley as Endangered. Turtles are also listed in Annex II of the SPAW Protocol, Appendix I of CITES (Convention on International Trade in Endangered Species of Wild Flora and Fauna), and Appendices I and II of the Convention on Migratory Species (Lagueux 2001).

Turtles may travel significant distances through multiple political jurisdictions during the estimated one to four decades required to reach sexual maturity. Adult females return to the general area where they were hatched, sometimes undertaking trans-oceanic journeys to lay their eggs (Box 1).

Box 1. Trans-oceanic range of Caribbean leatherback turtles revealed by tagging

- Nine leatherbacks satellite-tagged in Trinidad between 1995 and 2004: the three longest records documented post-nesting females returning to high-latitude Atlantic foraging grounds (as far north as the Flemish Cap) and continuing on to foraging grounds associated with the Mauritania Upwelling off the west coast of Africa (Eckert 1998 and 2006);
- Leatherbacks that have been satellite-tracked from Trinidad to Cape Breton, Nova Scotia and in the reverse direction: an adult male leatherback was tracked from Nova Scotia to Galera Point, Trinidad, where it resided for 96 days before returning to Nova Scotia (James et al. 2005);
- Eight post-nesting female leatherbacks satellite-tagged in Grenada in 2003: two traveled north-west, arriving within a few hundred kilometres of Cape Cod and Nova Scotia before turning southwards, while the remaining five traveled north-east, reaching latitudes between the Azores and the UK before some turned south (Hays et al. 2004a and 2004b).

The largest green turtle nesting colonies in the WCR are found at Tortuguero, Costa Rica (the largest in the Western Hemisphere and one of the two largest remaining in the world) and Aves Island, Venezuela (Carr et al 1982, Bräutigam and Eckert 2006). Smaller nesting rookeries are scattered throughout the region. These include Florida, Mexico (Tamaulipas, Veracruz and the Yucatán Peninsula), Belize, Panama, the coastline of northern South America, and at certain sites in the Eastern Caribbean (Carr et al 1982). The largest leatherback nesting colonies in the region are located in Trinidad and the Guianas (primarily French Guiana and Suriname). The latter is the world's largest insular nesting leatherback colony. The largest foraging aggregation of juveniles and adults is found on the extensive seagrass beds along the Caribbean coast of Nicaragua. Smaller foraging aggregations have been documented in Florida, the Yucatán Peninsula, Panama, the Guajira Peninsula of Colombia, the Lesser Antilles, Puerto Rico, Cuba, Jamaica, Grand Cayman, Bermuda and the southern Bahamas (Carr et al 1982). Marine turtles have become popular subjects for dive and nature tourism and, in this context, are increasingly becoming a source of revenue for coastal communities in the region, such as in Costa Rica, Grenada, St. Lucia, and Trinidad and Tobago.

Over 185 species of waterbird (seabirds, wading birds, marshbirds, waterfowl and shorebirds), including a number of endemic and globally threatened species, make their home in the Caribbean (Clay et al 2005). Seabirds are important predators in marine ecosystems, consuming small fish, crustaceans, and cephalopods. Twenty-three species of seabirds breed in the Insular Caribbean and a further 28 species winter in the region or migrate through it. Of the breeding species, one may now be extinct and at least two more, the Bermuda petrel and the black-capped petrel, are listed as Endangered. Overall, 11 species have been identified as at risk in the Caribbean (Bradley 2009). Although in some oceans seabirds are estimated to consume large amounts of fish, they are not generally seen as significant competitors with fisheries in the Caribbean. Seabird colonies are a source of nutrients and may locally enrich marine nursery areas around seabird colonies.

The Caribbean is also critically important for a number of North American breeding migrants (Neotropical migratory birds) during the boreal winter months. Migrant passerines in particular are disproportionately concentrated in this region and Central America (Wege 2005). Millions of birds representing approximately 350 species that breed in North America migrate each year to spend the winter in Latin America and the Caribbean. They include many species of songbirds, hawks, egrets, and ducks, among other well known groups. Additionally a smaller number of species migrate from South America to the Insular Caribbean to breed during the summer. The Insular Caribbean therefore shares these species with North and South America, and many spend up to nine months each year on the islands.

Many of the Venezuelan islands, including Los Roques Archipelago, Isla Las Aves, and Isla La Tortuga, serve as stopovers for North American migratory birds in their routes towards the south. Caribbean islands are the primary wintering grounds of a number of species, some of which are extremely rare, such as the Bachman's Warbler (*Vermivora bachmanii*). Unfortunately the long-term survival of about a third of these migratory species is of concern because of sustained declines in their populations over recent decades. The region's critical role as stop-over points, breeding, or wintering grounds for the numerous species is under threat as the importance of coastal habitats as stopover sites for birds is pitted against the desirability of coastal areas as prime real estate.

While coral reefs have declined over the past three decades, there are encouraging signs that recovery is occurring at local scales for sea turtles, whales, and sea birds.

2.3.4. Socioeconomic background

As previously mentioned, the CLME Region is the most geopolitically diverse and complex region in the world, with great cultural and economic diversity among its countries. Five hundred years of settlement by Europeans, Africans, Asians, and people from other parts of the Americas has resulted in a patchwork of independent states and colonies of governments in different regions (Table 1). This presents unique challenges to the establishment of the co-operative approaches needed to sustainably manage this ecosystem for the common good (CARSEA 2007).

The total population of the CLME countries and territories for which data are available for those listed in Table 2 is approximately 225,000 million (including Mexico). If Mexico is excluded (most of its population is located in the Gulf of Mexico LME), this estimate is about 113.4 million, of which about 36% are located in the Insular Caribbean. The average annual population growth rate for the period 2010 - 2015 is 0.76% for the Caribbean and 1% for Latin America (UN-ECLAC 2010). The resident population increases each year by the influx of millions of tourists, nearly all of whom end up on the region's beaches. In the World Bank's classification system, based on gross national income per capita, Caribbean countries are considered middle- and high-income, except Haiti, which is classified as low-income (Table 2). It is noteworthy that the countries with the four highest GDP/capita in the region are SIDs (Bahamas, Trinidad and Tobago, Barbados, and Antigua and Barbuda, in descending order). Among the Central/South American countries, Mexico has the highest GDP/capita, followed by Venezuela. After near-zero economic growth in 2000 and 2001, the region has been experiencing positive growth rates since 2003 (UN-ECLAC 2007). High levels of economic growth, however, mask persistent and in some cases increasing poverty. Studies carried out in 2003 showed that 25% of the Caribbean population can be considered as poor, with more women than men living in poverty (Trotz 2003). Significant variation exists among the countries with respect to poverty, with the highest proportion (65%) of population below the national poverty line being in Haiti (UNDP 2006).

With the exception of Haiti, Caribbean countries fall within the middle to high range on the Human Development Index (HDI), as shown in Table 2 (UNDP 2010). Among the CLME States, Antigua and Barbuda, Bahamas, and Barbados showed the highest HDI rank, with that of Barbados the highest in the region. Among the Latin American countries, Panama had the highest HDI rank, and Guatemala the lowest. Additional social indicators provided by UN-ECLAC (2010) show that life expectancy at birth for Latin America is 74.6 and the Caribbean 72.4 years; for the Latin America and Caribbean (LAC) region, illiteracy rate (above 15 years old) was 8.3% in 2010; this was higher among women

(8.8%) than men (7.7%); the proportion of the population with an improve drinking water source in 2008 was 93% and improved sanitation facilities 79%.

Table 2. Total population, GDP/Capita and Human Development Index (HDI) of CLME countries

(blank cells: no data available from sources consulted)

Country	[1]Total pop (000) (2011)	[2]GDP/Capita (2008 PPP US$)	[3]HDI (rank)
Antigua & Barbuda	89	19,117	**0.868 (47)
Aruba	108		
Bahamas	350	25,887	0.784 (43)
Barbados	257	22,794	0.788 (42)
Belize	319	6,460	0.694 (78)
Colombia	46,930	8,959	0.689 (79)
Costa Rica	4,703	11,143	0.725 (62)
Cuba	11,205		**0.863 (51)
Curaçao			
Dominica	66	8,967	**0.814 (73)
Dominican Republic	10,026	8,616	0.663 (88)
Grenada	105	8,424	**0.813 (74)
Guatemala	14,729	4,761	0.560 (116)
Haiti	10,253	1,040	0.404 (145)
Honduras	7,773	3,845	0.604 (106)
Jamaica	2,741	7,547	0.688 (80)
Mexico	111,738	14,192	0.750 (56)
Netherlands Antilles	203		
Nicaragua	5,896	2,632	0.565 (115)
Panama	3,562	13,210	0.755 (54)
Puerto Rico & US Virgin Is	4,123		

St. Kitts & Nevis	53	15,092	**0.838 (62)
St. Lucia	176	9,431	**0.821 (69)
St Vincent & the Grenadines	109	8,967	**0.772 (91)
Trinidad & Tobago	1,349	25,162	0.736 (59)
Venezuela	29,499	11,820	0.696 (75)
French Territories			
UK Territories	136		
[1] UN-ECLAC 2010. [2] UNDP International Human Development Indicators: http://hdr.undp.org/en/data/profiles/, based on UN DESA (2009). [3] UNDP Human Development Report 2009.			

In the LAC region as a whole, the majority of the population lives in urban areas. In fact, this is the most urbanized region in the developing world, with 77% of its population living in cities (UN Habitat 2008). The percentage of urban population in Latin America has been estimated at 77.8% and in the Caribbean at 64.3% (UN-ECLAC 2010). About 116 million live within 100 km of the coast in the region, with nearly three-quarters of the population in coastal zones being urban inhabitants (UN Habitat 2008). The region will continue urbanizing over the next two decades, with the proportion of the urban population reaching 85%. Many of these cities are in the vulnerable, low elevation coastal zone. Of the 3,351 cities in the low elevation coastal zones around the world, 64% are in developing regions; the LAC region accounts for 27% of the most vulnerable cities (Asia alone accounts for more than half of the most vulnerable cities and Africa for 15%). Cities embody some of society's most pressing challenges, from pollution and disease to unemployment and lack of adequate shelter and sanitation. Location in the coastal zone makes these cities very vulnerable to extreme meteorological events such as storms and hurricanes.

The CLME region has a long history of natural disasters caused by storms and hurricanes, floods, volcanic eruptions, landslides, and earthquakes. In the last decade, the region suffered from several major natural disasters whose magnitude, in terms of fatalities and damages, has been significant. This has renewed national governments' and international donors' interest in improving risk management (Charvériat 2000). In addition to causing fatalities, homelessness, and injuries, natural disasters represent an enormous cost for the affected countries as well as for the international community. For example, between 2002 and 2009, the LAC region experienced 69 storms (29 in the Caribbean), which caused a total of 6,483 deaths (62% in the Caribbean) and affected 11.3 million people (47% in the Caribbean) (UN-ECLAC 2010).

Hurricane season 2004 was particularly severe. In less than two months, four extremely dangerous hurricanes (Charley, Frances, Ivan, and Jeanne) pounded the Caribbean. These hurricanes caused severe loss of life, dangerous flooding, structural damage to roads, buildings, water and sewerage facilities and other infrastructure and devastation to agriculture and critical coastal habitats. The most notorious hurricane of 2004 was Hurricane Ivan, which devastated nearly the entire island of Grenada and caused widespread damage in other islands such as Barbados, Jamaica, and Tobago. The 2004 hurricanes caused about US$2.8 billion in damages in Cuba, Dominican Republic, Grenada, Haiti, and Jamaica (CRED 2005). Their limited financial and human resources, as well as narrow natural resource base implies that recovery of these small island states from disasters will be slow and long, and will rely to a large extent on external aid.

The Pan American Health Organization (PAHO) estimated that between 50,000 and 100,000 people were killed in the earthquake that struck Haiti in 2010, while the Red Cross estimated that 3 million persons — roughly one-third the country's entire population — have been directly affected by the earthquake. The annual average cost associated with natural disasters between 1970 and 1999 ranged between $700 million and $3.3 billion (Charvériat 2000).

Natural disasters are increasingly being viewed with a multidisciplinary focus, with the adoption of the term ‘socio-natural disasters’ that integrates both natural phenomena and societal vulnerability. Using this concept, Salas Serrano (2007) analysed the relative level of risk in nine Central American and Caribbean countries, eight of which are CLME countries (Table 3). These countries rank among the most exposed in the world to a number of risks, with the proportion of area at risk being higher than the world average in all of them and the proportion of population at risk higher than the world average in six of the eight countries (Table 3). This author found that the high degree of vulnerability (risk) combined with poverty are the primary causes of disaster-related destruction in these countries. Based on a combined assessment of risk and poverty, Salas Serrano (2007) determined the relative vulnerability of the countries, with Guatemala having the highest while Cuba and Panama the lowest (Table 3). Over a 33 year period (1972 to 2005), socio-natural disasters have resulted in 600,000 human lives lost, nearly 8 million directly affected, and more than US$25 billion dollars in material damage in these countries.

Table 3. Exposure of eight CLME countries to two or more types of risks

Country	Position among 60 countries most exposed to *two or more* types of risks	% total area at risk	% total population exposed	Maximum number of risk types	Relative vulnerability (descending order)
Costa Rica	7 (2[1])	80.4	69.2	4	11
Guatemala	10 (5[1])	56.6	83.4	5	18
Honduras	21	26.2	69.2	3	12
Mexico	31	16.5	62.6	4	5
Panama	35 (14[1])	15.0	9.6	3	2.5
Nicaragua	37 (15[1])	12.4	12.6	3	12.5
Dominican Republic	46	8.1	49.8	2	6
Cuba	49	6.6	6.2	2	2.5
Average (countries[2])		**18.6**	**56.36**		
Total (world)		**2.55**	**12.30**	**9**	

[1]Position among 15 countries most exposed to *three or more types* of risks
[2]Includes El Salvador

Two of the nine countries analysed by Sala Serrano (2007) are SIDS. Because of certain characteristics, the SIDS show particularly high environmental and socio-economic vulnerability to external perturbations. Another analysis that focused on the environmental vulnerability of Caribbean SIDS showed most of them are extremely or highly vulnerable and none of them resilient (Box 2).

Due to the disruption of economic activity and the loss of capital assets they provoke, natural disasters have had negative short-term effects on GDP growth. In many instances, disasters have also resulted in longer-term economic consequences, such as slower growth, higher indebtedness, and higher regional and income inequality. Environmental and social costs, though more difficult to assess in monetary terms, have also been substantial. A strong decrease in the number of victims from meteorological disasters was observed in 2009, compared to the annual average of 2000-2008. Although economic damages from meteorological disasters in the Americas decreased in 2009 compared to the 2000-2008 annual average, they were still the most costly disasters compared to other disaster types in 2009 (CRED Americas http://cred.be/sites/default/files/ADSR_2009.pdf). This underscores the importance of the region's coastal habitats for their coastal stabilization and protective function.

Box 2. Environmental and socio-economic vulnerability of SIDS

SIDS share a number of natural and anthropogenic features that make them particularly vulnerable to impacts from a wide range of internal and external forces (World Bank 2000, Kaly et al 2002). Among these features are geographic isolation; scarce land resources; economic dependence on a limited range of natural resources (in most cases coastal and marine resources); ecological uniqueness and environmental fragility; exposure to external and global changes in trade and markets; poverty; and high susceptibility to natural disasters (particularly climate-related) and global environmental change. A SIDS environmental vulnerability index, which integrates ecological fragility and economic vulnerability, has been developed by the South Pacific Applied Geoscience Commission, UNEP and their partners. Preliminary results (Kaly et al 2004) in the table below show that 17 of the countries can be classified as extremely vulnerable to highly vulnerable, four as vulnerable, and one at high risk, while none as resilient. (http://www.vulnerabilityindex.net/EVI_Results.htm).

All the Caribbean SIDS have adopted the BPoA, which identifies actions required at the national, regional, and international levels for their sustainable development and for reducing their vulnerability. Included in the priority areas identified in the BPoA are climate change and sea level rise, coastal and marine resources, tourism resources, and biodiversity resources.

*Vulnerability of some Insular Caribbean countries according to the SOPAC Environmental Vulnerability Index (*countries with insufficient data)*

Extremely vulnerable	Highly vulnerable	Vulnerable	At risk	Resilient
*Barbados *Guadeloupe Jamaica *St Lucia Trinidad & Tobago *British Virgin Islands *US Virgin Islands	Cuba *Cayman Is Dominican Republic *Grenada Haiti *Montserrat *Netherlands Antilles *Puerto Rico *St Kitts & Nevis St Vincent & the Grenadines	*Anguilla *Antigua & Barbuda *Aruba *Turks & Caicos	*Bahamas	***None***

Of particular concern is the effect of global warming, which is projected to lead to an increase in the frequency and severity of tropical storms (IPCC 2001). Based on global projections and studies in other regions, sea-level rise of 30 -55 cm for the Caribbean over the next 50 years is considered a reasonable projection. A rise of this magnitude is expected to have severe implications for the social and economic development of many Caribbean States (IPCC 2001), considering that about 70% of the Caribbean's population inhabits vulnerable low-lying coastal areas (UNEP 2000). It has been suggested that land loss from sea-level rise, especially on the low limestone islands, is likely to be of a magnitude that would disrupt virtually all economic and social sectors (Leatherman 1997).

This is of grave concern among the Insular Caribbean countries. The ratio of coastline to land area is an indicator of 'islandness' or the proximity of the interior of the island to the coast: the larger the quotient, the more 'island-like' the country. The topography and hydrology determine the nature and extent of the land–sea interaction, which defines the coastal zone. 'Coastal zone' is considered as the area between the landward limit of marine influence and the seaward limit of terrestrial influence. Because of their small physical size, the entire landmass of some of these small islands can be considered as coastal, which has serious implications with regards to the impacts of global warming and sea level rise.

The high dependence of the CLME countries on the marine environment and living marine resources, combined with their high environmental vulnerability underscores the importance of conserving this environment and sustainably exploiting these resources, especially with regard to a changing global climate over which these countries have little or no control. It is imperative that the coastal habitats are maintained in a healthy condition to increase their resistance and resilience to the impacts of internal and external anthropogenic and natural pressures.

The marine and coastal areas of the CLME have a number of frequently coexisting socioeconomic uses, the most important of which are:

- Fishing
- Tourism
- Urban settlements
- Industrial development
- Maritime-port activity
- Forest industry activity (cutting down coastal forests and mangroves)
- Extraction of sand for the construction industry

Among these, the main economic activities of Caribbean countries include tourism, construction (much of which is tourism-related), mining and oil extraction (Brown et al 2007). Other sectors include manufacturing and finance. The petroleum industry is a major economic sector in Venezuela, Mexico, and Trinidad and Tobago, the region's three largest oil exporters. Oil and natural gas exploration, extraction, refining and transportation are key activities in these countries, accounting for 30%, >10% and 40% of GDP, respectively. Much of the oil exploration, extraction, refining, and transportation activities take place in marine and coastal areas of the CLME. This places tremendous pressures on this ecosystem, including from pollution and coastal habitat destruction. The Caribbean Sea is noted for its maritime industry, with tens of thousands of cargo vessels, cruise ships, fishing and recreational vessels plying the waters of the Caribbean Sea each year. With between 10 - 15 thousand ship crossings annually, the Panama Canal is the world's leading maritime hub and accounts for about 30% of Panama's GDP. The Panama Canal is currently undergoing a US$5.25 billion expansion that will allow it to accommodate larger ships. The agricultural sector has declined in recent years as a result of the development of tourism and the decline of preferential export markets. Nevertheless, this sector remains socially and economically important in many countries.

Two sectors that are heavily dependent on the ecosystem services of the Caribbean Sea ecosystem are fishing and tourism. Data for this analysis have been obtained from different sources, each of which presents the data differently and in varying levels of details or different time periods. For example, in the Food and Agriculture Organization (FAO) country profiles, some countries include the contribution of fisheries to GDP in the agricultural sector contribution, others present the total number of boats while others present a breakdown by type of vessels. The FAO fishery and aquaculture yearbook presents fish supply per capita (that is, fish available for consumption by dividing total fish production by total population), which might not be the same as actual fish consumption per capita. Similarly, for the Central American countries, contribution to GDP is combined for fisheries and aquaculture while fish consumption per capita per year is presented. Further, in the continental CLME, most of the countries have coastlines in the Caribbean Sea as well as in the Pacific Ocean, and data are often reported at the country level for both areas combined, which further compounds the issue of obtaining data specific to the CLME. Another constraint in conducting separate analyses for the reef and pelagic ecosystems is that the data are usually combined for these systems. For example, the number of fishing vessels is usually reported as a total by country, with no distinction between those fishing for reef and pelagic species. Moreover, it is very common that the same fishers will exploit both reef and pelagic species at different times and even at the same time. These complexities make it difficult if not impossible to report certain statistics for each ecosystem individually.

The foregoing underscores some of the challenges in obtaining data at the country level in a consistent and homogenous format for the CLME. For fisheries statistics and indicators, this problem is partly address by the Sea Around Us Project of the University of British Columbia (UBC) (http://www.seaaroundus.org/lme/12.aspx), which produces a number of fisheries indicators by countries and LMEs based on data from FAO and other sources. As this project adjusts (corrects) any discrepancies in primary fisheries data at the country data, the adjusted data would be different from what is reported by the countries. Despite the variability among sources, however, the data presented are valuable in demonstrating general trends among the countries and within the region.

The Caribbean fishing industry showed little expansion until the second half of 20th Century (Christy 1997). Prior to this, the fisheries were limited to subsistence and artisanal levels in nearshore areas. In the 1970s, especially after the declaration of the Exclusive Economic Zone (EEZ) regime, several countries (e.g. Mexico, Cuba, Colombia, Nicaragua, Panama, and Venezuela) implemented government-sponsored fisheries expansion programmes involving both nearshore and offshore fishing fleets. Countries such as Trinidad, Colombia, Cuba, Mexico, and Nicaragua even established government fishing companies. This expansion was accompanied by subsidization programmes involving loans for vessels, gear purchases, and fuel tax rebates in several Caribbean countries (Mohammed et al 2003).

The fisheries of the Caribbean Sea are predominantly multi-species, multi-gear, small-scale artisanal fisheries. In the Central American countries, for example, 90% of the fishers and 97% of the sub-regional fishing effort are artisanal (FIINPESCA–

OSPESCA/FAO/SUECIA 2009). Caribbean fisheries are conducted by low-capital, labour-intensive operators, with the main exceptions being the industrial shrimp and tuna fisheries, as well as fisheries for high-value reef species such as conch, lobster, snapper, and grouper. Despite the high species diversity in the CLME, only a relatively small number of species are targeted, and each country may display its own peculiarities regarding the major species caught, gear used, and other features.

Table 4 shows the contribution of fisheries to GDP (for some countries this is combined with aquaculture and for others included in agricultural GDP) as well as travel and tourism to GDP. It is evident that fisheries do not play a very significant role in terms of national wealth generation compared to tourism. Contribution of the agricultural/fisheries/aquaculture sector to GDP does not exceed 8% for any of the countries, attaining this level only in Barbados followed closely by St. Lucia with 7.3%. Among the Central and South American countries, Nicaragua and Honduras show the highest contribution of this sector to GDP. Despite the relatively low contribution to GDP, the impact of fisheries is considerable, including in terms of employment and protein supply. Small-scale fisheries in particular are widely recognized as an integral part of the fisheries sector in all CLME countries and play an important role in sustainable development, especially with respect to key issues such as poverty reduction, food nutrition, and livelihood security, wealth creation, foreign exchange earnings, and coastal-rural development (CARSEA 2007). The fisheries sector is primarily seen as an "economic safety net" to complement other employment activities (e.g. the construction and tourism sectors).

The fisheries sector provides stable full-time and part-time direct employment for more than 300,000 people in fishing, processing, and marketing (CARSEA 2007). Based on an estimate of five dependants for each person employed in the fisheries sector, it was estimated that over 1.5 million people in the Caribbean rely on fisheries for their livelihoods (CARSEA 2007). Data compiled for these TDAs indicate at least one million persons are employed in fishing and related activities[4] (Table 5), considering that data are missing for some countries. Based on the CARSEA estimate of five dependants for each person employed in this sector, the number of persons in the Caribbean who rely on fisheries for their livelihoods is at least 5 million. Indirect employment is also provided by support industries such as boat-building and net-making. People engaged in fishing often have low levels of formal education, limited access to capital, and limited occupational and geographic mobility. Therefore, they will be highly impacted by declines in living marine resources.

It is obvious that sustainable fisheries are as necessary as sustainable tourism for the national economies. Yet, despite the cultural and socio-economic importance of the fishing sector for millions of people in the region, in some Caribbean countries investments in fisheries and fisheries sustainability have been very low compared to the huge investments in tourism infrastructure and development during the last 10 years.

[4] Some countries report only numbers of fishers, while others report a combined total of fishers and employment in processing and marketing

For example, investment in travel and tourism in 2010 alone was estimated at US$10.2bn or 20.4% of total investment in the Caribbean Islands and US$48.3bn or 7.6% of total investment in Latin America (Boxes 3 and 4).

Table 4. Contribution of fisheries and aquaculture, and travel and tourism to national GDP of CLME countries

(blank cells: no data available from sources consulted)

Country	[1,2]% Fisheries & aquaculture Contribution to GDP	[3]Travel & tourism % Contribution to GDP (2010)
Antigua & Barbuda	1.3	78.5
Bahamas	1.6	46.5
Barbados	8% agric. GDP	48.0
Belize	4.15	28.2
Colombia	3.86	5.3
Costa Rica	1.38	14.0
Cuba	6.8	5.9
Dominica		23.3
Dominican Republic		15.9
Grenada	1.76	24.3
Guatemala	0.44	7.6
Haiti		7.0
Honduras	5.25	9.5
Jamaica	6.0 (agric GDP)	25.3
Mexico	0.8	12.7
Nicaragua	5.62	7.2
Panama	2.49	13.7
St. Kitts & Nevis	3.8	30.5
St. Lucia	7.3 (agric)	35.1
St Vincent & the Grenadines	2.0	26.5
Trinidad & Tobago	0.09	36.8
Venezuela	4.5 (agric)	7.1

1 FIINPESCA–OSPESCA/FAO/SUECIA 2009.
2 FAO Fishery Country profiles (http://www.fao.org/countryprofiles/default.asp?lang=en)
3 World Travel & Tourism Council 2010 (http://www.wttc.org/eng/Tourism_Research/Economic_Data_Search_Tool/index.php)
* 2007- GDP in the primary sector "Agriculture, forestry, hunting and fishing" 2000 - 2007 (at current prices in millions of U.S. dollars).

Data compiled for these TDAs (Table 5) show that the region's fishing fleet consists of about 29,850 boats (excluding Mexico because of the relatively small proportion of its coastline in the CLME and unknown number of boats in this area, and a few countries for which data were unavailable). CARSEA (2007) reported a total of 31,500 boats (approximately 25,000 artisanal boats, 5,000 medium-sized boats, and 1,500 industrial vessels). These estimates are likely to be higher, because of missing data.

In general, fish consumption per capita is higher in the Insular Caribbean compared to the continental states, which demonstrates the dependence of the islands' population on the CLME fish resources. Fish protein supply per capita exceeds the world average of 4.5 g/day in 11 of the countries, 10 of which are in the Insular Caribbean (Table 5). Fish protein as a percentage of total animal protein exceeds the world average in eight countries, all of which are in the Insular Caribbean. In addition, a high demand for fish is seen in the tourism sector, both for direct consumption and recreational fishing. In terms of value, the biggest importers of fish are Mexico, Venezuela, and Colombia, while Mexico, Panama, and Colombia are the three top exporters (Table 5). Exports of fish products are dominated by high-value commodities such as shrimp, spiny lobster, tuna, snappers, groupers, and queen conch, all of which command premium prices on the international market. The USA is the major destination of most fish exports from the Caribbean, which have been growing steadily in value.

Table 5. Socio-economic importance of the fisheries sector in CLME countries

Country	[1,2]No. employed in fisheries	[1,2]No. vessels	[3]Fish protein supply per capita (g/day)	[3]Fish/animal protein %	[3]Fish Imports value (000 US$)	[3]Fish exports value (000 US$)
Antigua and Barbuda	1,193		14.1	24.6	7,882	327
Bahamas	9,300	4,000 (reef mainly)	7.7	12.6	17,806	83,367
Barbados	2,825	485 (reef, coastal); 300 (flyingfish & large pelagics); 30 longliners	11.3	22.0	18,847	899
Belize	3,843	593 (artisanal)	3.5	11.6	1,541	20,866
Colombia	28,485 (industrial); 26,700 (aquaculture); 66,000 (smallscale marine and inland)		1.6	5.4	174,105	188,690
Costa Rica	1,210	242	2.1	6.3	44,972	107,255
Cuba	16,710	1,306	2.2	9.7	49,188	81,000
Dominica	2,903	>1,100 (10 tuna longliners)	8.3	16.7	1,815	6
Dominican Republic		3,752	2.8	10.3	102,195	4,937
Grenada	2,800 ([4]2,515)	480 (pelagic); 130 (reef-fish); 50 (bait); 100 (lobsters, conch) ([4]1695 reg. vessels)	11.1	22.1	4,701	4,115

Guatemala	1,420	465	0.7	4.7	43,852	89,640
Haiti			0.8	10.1	17,014	4,879
Honduras	10,766 (artisanal)	5,383 (artisanal)	0.9	3.4	19,080	186,934
Jamaica	20,480	4,154	7.6	19.0	94,406	9,231
Mexico	268,727 (primary sector)	106,425	3.3	8.0	540,423	830,207
Nicaragua	5,676 (artisanal)	1,892 (artisanal)	1.1	6.2	6,599	96,448
Panama	2,280 (artisanal)	760 (artisanal)	3.9	10.5	24,999	362,304
St. Kitts & Nevis	600 (primary sector); >75% in reef fisheries		8.7	16.7	3,927	434
St. Lucia	2,339	690	12.6	21.4	6,810	11
St Vincent & the Grenadines	2,050 ([4]900 registered fishers)	600 ([4]745 registered vessels)	4.9	12.2	1,260	362
Trinidad & Tobago	7,085	2,264	6.1	19.7	25,655	8,723
Venezuela	786,600	65 (tuna)	4.8	14.0	187,244	33,018
			4.5 (World)	**15.6 (World)**		

[1]FAO Fishery Country profiles (http://www.fao.org/countryprofiles/default.asp?lang=en)
[2]FIINPESCA–OSPESCA/FAO/SUECIA 2009.
[3]FAO (2009). Yearbook of Fisheries and Aquaculture Statistics 2007. FAO, Rome.
[4]Data provided by countries in response to survey by CLME project.

Overall, the aquaculture industry is well-developed in only a few countries. The industry is primarily based on the production of white shrimp (*Litopenaeus vannamei*) and *Tilapia*, although a number of other species are commercially farmed. In the Insular Caribbean, there is some small-scale production of tilapia and seaweeds *(Gracilaria).* The culture of marine fish is limited to experimental production of species such as cobia in Colombia and Cuba, and conch in Turks and Caicos.

Additional statistics for the fishing and aquaculture sectors in the Central American countries are presented in Tables 6 and 7. Panama and Honduras have the highest fisheries landings and number of boats and jobs, although the per capita fish consumption is very low in Honduras compared with Panama. In this sub-region, aquaculture production, mainly of shrimp and tilapia, surpasses fish capture production in four out of the six countries that border the CLME. This trend is most pronounced in Honduras where aquaculture production in 2007 amounted to about 17 times more than capture production. Honduras is also the sub-region's biggest aquaculture producer, followed by Costa Rica (Table 7). Aquaculture is one of the fastest growing industries in Belize and over the last five years has surpassed the earnings from lobster and conch that have been Belize's most important fisheries revenue earners. While the culture of aquatic organisms consists largely of freshwater species, this can have deleterious impacts on coastal habitats when waste and contaminated effluents are disposed of in coastal areas. (to be expanded if data available from other countries).

Despite the large number of countries that exploit the fisheries resources of the CLME, the catch is dominated by only a few countries, with Venezuela, Cuba, Mexico, and Jamaica accounting for nearly 80% of the total catch of about 364,000 tonnes in 2006 (Figure 4). This could be partly attributed to the large EEZs of these countries relative to those of the other CLME countries. The fairly steady trend in total annual landings has probably been maintained by an increasing fleet capacity in the region and expansion to other fishing areas.

Table 6. Socio-economic importance of fisheries in Central American countries (2007)

Countries	Fish landings (mt)	Aquaculture production (mt)	No. boats artisanal	Employment artisanal	No. boats industrial	Employment Industrial	Per capita consumption (kg/yr) in 2007
Belize	635.67	2,637.37	593	3,843	0	0	10.82
Costa Rica	27,122.2	25,299	4,065	16,502	73	365	12.71
Guatemala	15,227.4	16,400	4,395	8,795	71	430	2.22
Honduras	2,520.2	43,187	8,594	17,188	268	5,418	2.93
Nicaragua	11,075	11,431.1	4,155	12,163	141	2,904	2.13
Panama	224,548.8	8,309.6	9,558	28,674	666	4,092	19.14
Source: FIINPESCA – OSPESCA/FAO/SUECIA 2009.							

Table 7. Aquaculture production (metric tonnes) by CLME countries

(data from other countries needed)

Species/Country	Belize	Costa Rica	Guatemala	Honduras	Nicaragua	Panamá
Shrimp	2,472.37	5,274	13,500	30,367	11,097.5	8,263
Tilapia	165	19,489	2,900	12,820	333.7	46.6
Trout		536				
Source: FIINPESCA – OSPESCA/FAO/SUECIA 2009.						

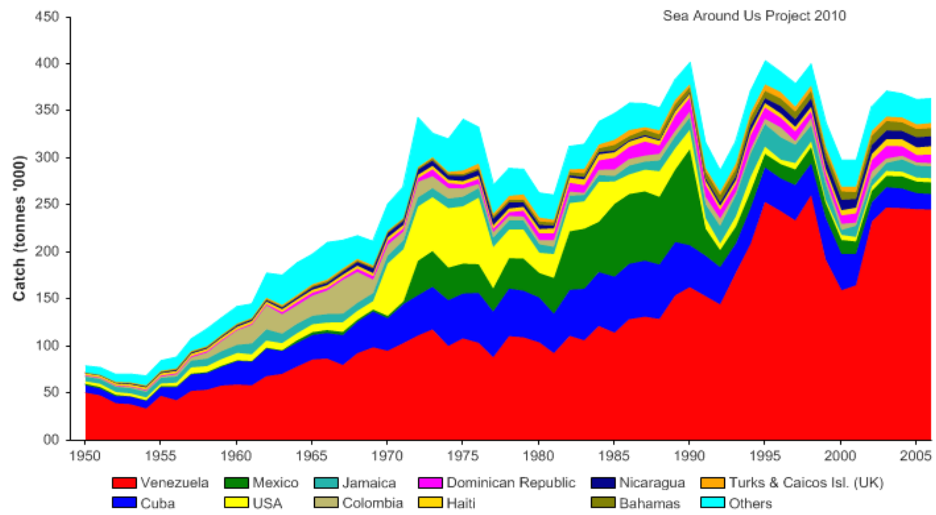


Figure 4. Annual catch by countries in the CLME from 1950 to 2006

In 2006, the value of the total landings was about US$533 million (Figure 5), 65% of which was attributed to only five countries (Bahamas, Cuba, Jamaica, Nicaragua, and Venezuela). Significant proportions of high-value species such as lobster, conch, and tunas in the landings of these countries account for the relatively high value.

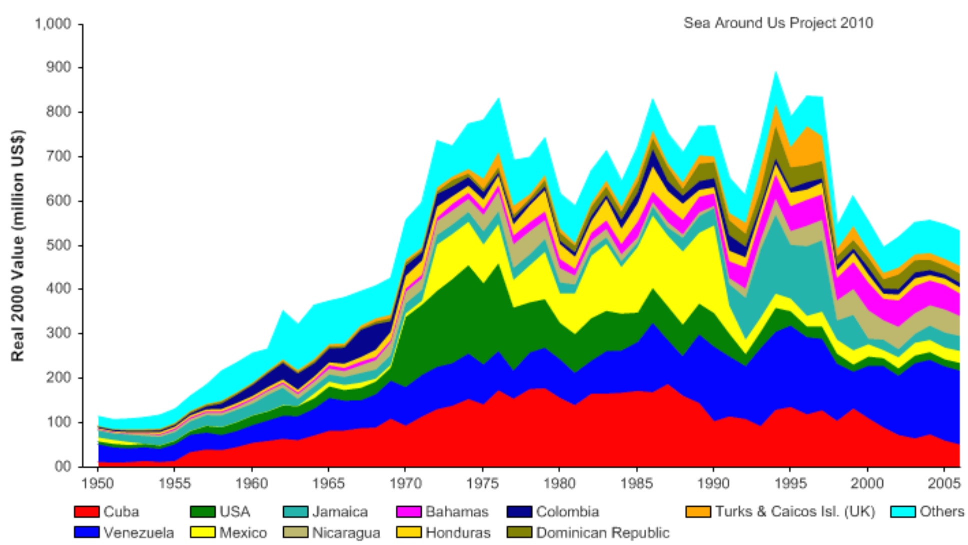


Figure 5. Value of fisheries landings by countries in the CLME from 1950 to 2006

Another economic sector that is highly dependent on the amenity value or cultural ecosystem services of the CLME is tourism. Important attractions for Caribbean tourism are sandy beaches, clear waters, colourful and biologically diverse coral reefs, picturesque coastlines, and sailing and recreational fishing, especially in the Insular Caribbean. The dependence of tourism on coastal and marine areas and living marine resources as well as the concentration of tourism infrastructure and activities on the coast causes major environmental problems for the very living resources that support tourism. Tourism is an important sector in a number of the countries, especially in the Insular Caribbean (Table 4). Tourism has become one of the principal industries and the fastest growing economic sector in the sub-region (CARICOM Secretariat 2003). The high dependence of the economies of some of the countries on tourism is evident in its contribution to GDP, which reaches nearly 79% in Antigua and Barbuda and over 30% in the Bahamas, Barbados, St. Kitts and Nevis, St. Lucia, and Trinidad and Tobago.

According to data from the Caribbean Tourism Organization (CTO 2002) in 2000 almost 25 million tourists traveled to the Caribbean. In 2004 close to 10 million tourist arrivals and a similar number of cruise ship passenger visits were recorded in 12 of the Caribbean SIDS. This represents an increase of between 13.4% (Cuba) and 106% (Dominica) over the previous year. In 2006, the number of tourists recorded in the Central American countries (excluding El Salvador) was about 5,681,432 with Costa Rica followed by Guatemala having the highest (about 1.7 and 1.5 million, respectively), and Belize the least with about 247,000 (SICA 2011). Despite the lower number of tourists in Belize, the contribution of the tourism sector to this country's GDP is highest among the continental countries (28.2%) followed by Costa Rica (14%) (Table 4). This underscores the high relative importance of tourism to the economy of Belize.

The number of rooms providing tourist accommodation in the region (including Cancun, Cozumel, Venezuela, and Belize) increased by more than 132% between 1990 and 2000, from 122,000 to almost 283,000 (CARSEA 2007). In 2000, the Dominican Republic recorded the largest number of rooms (51,916), followed by Venezuela (33,149), Cancun/Mexico (25,434), and Jamaica (23,640). The hotel sector, however, is rivaled in bed/berth capacity by the cruise ship sector, the fastest-growing tourism segment (McElroy 2004). The total number of cruise-ship passenger arrivals in the Caribbean was 14.6 million, with the most frequent ports of call being in the Bahamas (2.5 million), U.S. Virgin Islands (1.8 million), Cozumel, Mexico (1.5 million), Puerto Rico (1.3 million), and Cayman Islands (1.0 million).

Statistics from the World Travel and Tourism Council (2010) presented in Boxes 3 and 4 show the importance of travel and tourism in terms of contribution to national economies and employment (current and projected to year 2020) for the Caribbean Islands and Latin America (separately). Of particular interest is that in the Caribbean Islands, travel and tourism rank first in relative contribution to national economies, with real GDP growth of 4.1% per annum over the coming 10 years (Box 3). Relative to its size, the Insular Caribbean is the most tourism-driven region in the world. In terms of jobs and export income, the contribution of tourism is nearly double that of the global average, and accounts for more than a fifth of all capital investment in the region (CARSEA 2007).

Box 3. Statistics from the World Travel and Tourism Council (2010) for the Caribbean Islands

World ranking: The Caribbean Travel and Tourism economy is ranked 13th in absolute size worldwide, 1st in relative contribution to national economies, and 10th in long-term (10-year) growth. GDP: The contribution of Travel & Tourism to GDP is expected to rise from 12.3% (US$39.4bn) in 2010 to 12.8% (US$76.3bn) by 2020. Employment: The contribution of the Travel & Tourism economy to employment is expected to rise from 1,829,000 jobs in 2009, 10.8% of total employment or 1 in every 9.2 jobs to 2,391,000 jobs, 11.9% of total employment or 1 in every 8.4 jobs by 2020. Growth: Real GDP growth for Travel & Tourism economy is expected to be -0.6% in 2010 and to average 4.1% per annum over the coming 10 years. Visitor Exports: Export earnings from international visitors and tourism goods are expected to generate 15.7% of total exports (US$23.5bn) in 2010, growing (nominal terms) to US$45.6bn (16.0% of total) in 2020. Investment: Travel & Tourism investment is estimated at US$10.2bn or 20.4% of total investment in 2010. By 2020, this should reach US$18.4bn or 20.2% of total investment.

For the Latin American countries, travel and tourism rank 13th in relative contribution to national economies, with real GDP growth of 5.1% per annum over the coming 10 years (Box 4). In the continental countries, while tourism makes a lower contribution to GDP than in the Insular Caribbean countries, the number of jobs in this sector is at least ten times more as a result of their larger population sizes. In terms of the proportion of total employment, however, jobs in the tourism sector in the Insular Caribbean has a higher proportion of all jobs (10.8%) compared with the continental countries (6%). Individual countries in the Insular Caribbean may show an even higher proportion of employment in tourism, such as in the Bahamas where tourism and its related activities provide employment for approximately 50% of the workforce.

Box 4. Some statistics from the World Travel and Tourism Council (2010) for Latin America

(includes all countries and not only CLME countries)

World ranking: The Latin America Travel and Tourism economy is ranked 5th in absolute size worldwide, 13th in relative contribution to national economies, and 7th in long-term (10-year) growth.

GDP: The contribution of Travel & Tourism to GDP is expected to rise from 6.2% (US$200.2bn) in 2010 to 7.0% (US$361.5bn) by 2020.

Employment: The contribution of the Travel & Tourism economy to employment is expected to rise from 11,814,000 jobs in 2010, 6.0% of total employment or 1 in every 16.6 jobs to 16,336,000 jobs, 6.7% of total employment or 1 in every 14.9 jobs by 2020.

Growth: Real GDP growth for Travel & Tourism economy is expected to be 1.4% in 2010 and to average 5.1% per annum over the coming 10 years.

Visitor Exports: Export earnings from international visitors and tourism goods are expected to generate 5.3% of total exports (US$29.3bn) in 2010, growing (nominal terms) to US$65.5bn (5.2% of total) in 2020.

Investment: Travel & Tourism investment is estimated at US$48.3bn or 7.6% of total investment in 2010. By 2020, this should reach US$110.7bn or 9.4% of total investment.

As the fastest-growing economic activity in the region, tourism makes a significant contribution to employment and foreign-exchange earnings, and has important economic linkages with other sectors such as fisheries, agriculture, and construction. The expected growth in tourism, much of which is associated with coastal and marine areas, will put increasing pressures on the Caribbean Sea ecosystem and living resources. This growth will be accompanied by increasing demand for living marine resources for food and coastal space for tourism infrastructure, increase usage of marine habitats such as coral reefs, and greater waste generation by this sector.

3. REEF ECOSYSTEM AND SOCIO-ECONOMIC SETTING OF THE CLME

3.1. Fishery ecosystem oriented setting

3.1.1. Reef ecosystem

For the purposes of the CLME TDA, the reef ecosystem is considered to comprise the following:

- Coral reefs (shallow water)
- Estuaries and lagoons
- Mangroves
- Seagrass beds
- Beaches
- Deep water reefs and rocky outcrops along continental shelf edge and slope).

Although the focus of many studies and management practices (such as Marine Protected Areas- MPAs) is on coral reefs, these systems cannot be considered in isolation from adjacent coastal habitats such as mangroves and seagrass beds. In many places throughout the region, however, mangroves and sea grass beds have been destroyed, with only the adjacent coral reef left. Caribbean marine ecosystems are inextricably linked through the movement of living organisms as well as pollutants, nutrients, diseases, and other stressors (Grober-Dunsmore and Keller 2008). Coral reefs, mangroves, and seagrass beds represent an integrated and interacting set of ecosystems (Mumby and Hastings 2008), with high connectivity[5] between them. Of particular interest is demographic connectivity, defined by Mora and Sale (2002) as the demographic connection between populations due to the migration of individuals (especially larvae) between them.

There are a growing number of studies that show that the ability of an ecosystem to recover from disturbance (i.e. ecosystem resilience) may be influenced by habitat connectivity (e.g. Mumby 2006a, Mumby and Hastings 2008, Botsford et al 2009, Steneck et al 2009). Ecosystem connectivity may increase the resilience of Caribbean reefs to external perturbations including climate-induced changes such as hurricane disturbance and coral bleaching. Factors that appear to improve the resilience of coral reefs include good connectivity to unimpacted or resistant reef areas, enabling coral larvae to move in and re-establish the coral population; abundant herbivore populations to graze on algae, maintaining space on the reef surface for corals to recolonize; and the absence of other local threats such as pollution and sedimentation. Despite the potential for resilience,

[5] Connectivity can be broadly defined as the exchange of materials, organisms, and genes and can be divided into: 1) genetic or evolutionary connectivity that concerns the exchange of organisms and genes, 2) demographic connectivity, which is the exchange of individuals among local groups, and 3) oceanographic connectivity, which includes flow of materials and circulation patterns and variability that underpin much of all these exchanges (Grober-Dunsmore and B.D. Keller, eds. 2008).

however, there is already evidence of a growing number of reefs for which recovery has been minimal, even over a decade or longer (Burke et al 2011).

Connectivity considerations have great implications for the management of coral reefs. For demographic connectivity to contribute to the resilience of coral reefs, it must improve nursery habitats on or near reefs and enhance the reproductive output of ecologically important species throughout coral reef ecosystems (Steneck et al 2009). Yet, throughout the region these habitats are often considered as separate systems when they should be considered together as one large, interdependent marine ecosystem with shared biodiversity for management purposes (e.g., in design and management of MPAs). In fact, because of high connectivity among the various components and the shared and transboundary nature of the living resources and drivers of change, the CLME should be managed as a whole, integrated system.

The life history of most marine organisms includes an obligate period of pelagic larval dispersal. Migration to spawning areas and pelagic larval dispersal often extends well beyond the home range of these organisms. Particular habitats such as seagrass beds and mangrove forests play a functional role in maintaining reef fish and invertebrate populations in the Caribbean. Mangroves and seagrass beds function as nursery habitats for many reef-dwelling organisms such as lobsters and reef fishes, particularly in the Caribbean (Steneck et al 2009). These coastal ecosystems are mainly utilized by juveniles and young adults, and are considered essential and critical fish habitats[6].

In the Caribbean, juvenile reef fish occupy the submerged mangrove prop roots and make frequent foraging runs into adjacent seagrass beds (Mumby 2006a). A number of reef fish in different trophic groups: herbivores (e.g., *Scarus iserti*, *S. guacamaia*), invertivores (*Haemulon sciurus*, *H. flavolineatum*, *H. plumieri*), and piscivores (*Lutjanus apodus*, *Sphyraena barracuda*) use mangroves and seagrass beds as juveniles and coral reefs as adults. It is suggested that several species sequentially utilize seagrass beds first and then mangroves before migrating to coral patch reefs and the outer fore reef. In the Caribbean, the presence of prolific mangroves in the vicinity of coral reefs was found to exert a profound impact on the community structure of 162 species of reef fish and greatly elevated the total adult biomass of several species, many of which are economically and/or ecologically important (Mumby et al. 2004). The Caribbean parrotfish, the largest herbivorous fish in the Atlantic, has become locally extinct in areas where mangroves have been removed (Mumby et al. 2004). Juveniles of Cubera snapper (*Lutjanus cyanopterus*), the largest snapper species in the Western Atlantic, inhabit shallow mangrove habitats whereas adults generally inhabit deep fore reef environments (Heyman et al 2005).

While early models and evidence from genetics suggested that long distance dispersal of larvae is likely a common event leading to considerable population connectivity among distant populations, more recent evidence strongly suggests that local retention is more the rule, and that long distance transport is likely insufficient to sustain marine populations over demographic timescales. Nevertheless, owing to the circulation patterns, as well as

[6] Essential and critical habitat as been defined by U. S. Congress as those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.

the close proximity and ecological similarity among the countries, dispersal of larvae across EEZs is not unlikely. Therefore, even the coastal resources have an important transboundary component to their management. As shown by Paris et al (2005) in a study of larval transport pathways from Cuban snapper spawning aggregations, in addition to considerable levels of self-recruitment (ca. 37 to 80 % total recruitment), the northern Cuba snapper populations exported larvae to the southern Bahamas, specifically to Cay Sal Bank (ca. 11 to 28 % total recruitment). These concepts need to be taken into account in developing management strategies for the CLME's living marine resources.

Many Caribbean reef fish species, including commercially important snappers and groupers, form dense spawning aggregations at specific locations during certain periods of the year. These aggregations are heavily exploited and some have become locally extinct. Aggregations within the Mesoamerican Reef and their management applications are discussed by Heyman et al (2008). The formation of spawning aggregations may enhance connectivity among isolated subpopulations within a meta-population (Nameth et al 2008). These brief periods of annual reproduction are the most critical and most vulnerable life-history event for aggregating species that contribute to subsequent generations, sustain local or meta-populations, and support valuable fisheries.

In the Caribbean Sea, coral reefs cover about 26,000 km^2 (Burke and Maidens 2004), seagrass beds about 66,000 km^2 (Jackson 1997), and mangroves nearly 11,560 km^2 (FAO 2003a). The coral reef-mangrove-seagrass complex is one of the most biologically diverse and productive systems in the world. Caribbean coral reef habitats, seagrass beds and mangroves provide important goods and services both individually and through functional linkages. In the low productivity Caribbean Sea 'desert', the highly productive coral reefs, mangroves, and seagrass beds are among the few 'oases', that are responsible for nutrient cycling and carbon and nitrogen fixation in this nutrient-poor environment. Coastal habitats have important transboundary significance in that they harbour high genetic and biological diversity and serve as feeding and nursery grounds for fish and invertebrate species with transboundary distribution either as larvae or adults. Mangrove forests and seagrass beds are important carbon sinks, which is pertinent to the issue of rising concentration of greenhouse gases and global warming. On the other hand, stony corals and other calcareous organisms are very susceptible to increasing carbon dioxide concentration in sea water (acidification), which can dissolve or impair formation of their carbonate skeletons.

Tight interspecies interactions and energy recycling within reef systems help to maintain ecosystem structure and function, and hence ecosystem resilience. Reef fish are typically bottom dwellers with a close association with habitat. Some of them, such as snappers and groupers, display strong fidelity to certain sites. The health of these ecosystems is critical to maintaining the ecosystem services they produce (see following section), yet they are increasingly subjected to anthropogenic pressures from both land and sea based sources as well as to the impacts of climate change. Ecosytem based management (EBM) promotes the maintainance of overall ecosystem health, productivity, and system resilience.

While Caribbean reef fisheries are predominately dependent on nearshore coral reef ecosystems, deep water coral reefs also support valuable fisheries for snappers and similar species throughout the CLME. These are not independent, however, of coastal ecosystems. Inshore habitats such as mangrove lagoons, coral reefs, and seagrass beds are known nursery areas for juveniles of many of the species caught on deep slopes and banks as adults.

Coastal habitats including coral reefs, seagrass beds, mangroves, beaches with turtle nesting sites, estuaries and lagoons, and fish spawning aggregation sites are among the priority conservation targets identified in the MAR system in the Nature Conservancy ecoregional assessment for the MAR (Arrivillaga and Windevoxhel 2008). The interdependent nature of these marine ecosystems is a vital consideration in EBM of the CLME, as degradation of one type of habitat can have far reaching impacts on the services provided by another.

A brief description of the habitats that comprise the reef ecosystem (in the context of these TDAs) follows:

- ***Coral reefs***

Coral reefs occur throughout the Caribbean and are especially well developed in areas with little or no riverine inputs. Estimates of the percentage of the world's coral reefs that occur in the CLME range from 7% (Burke and Maidens 2004) to 9.5 % (Sea Around Us Project 2010). Coral reefs are second only to tropical rain forests in terms of biodiversity and productivity. Their rich biodiversity is due in large part to their highly complex architecture that provides shelter and resources for a wide range of invertebrate and vertebrate species. Despite the high biodiversity of reef organisms, however, the abundance of individual species is relatively low, as is typical of tropical marine ecosystems. This must be an important consideration in the development of management strategies for the reef fisheries. Stony corals (scleractinians) are the group primarily responsible for laying the foundations of, and building up, reef structures. Symbiotic algae (zooxanthellae) provide food for many shallow-water corals through photosynthesis. They also assist in the formation of the calcareous skeleton, and give most tropical corals their coloration.

The WCR is heavily dominated by fringing reefs and the entire Caribbean region contains only two true barrier reefs. Extending 220 km from the southern part of the Yucatan Peninsula to the Bay Islands of Honduras, the MesoAmerican Reef system is the longest barrier reef in the Western Hemisphere. A smaller barrier reef lies north of Providencia Island (Colombia) in the southwest Caribbean. In the Greater Caribbean region some 500-600 species of fishes are associated with coral reef ecosystems, many of them dependent on mangroves and seagrasses. In addition to demersal reef fish, a number of pelagic species are associated with coral reefs (e.g. barracuda, turtles) as are numerous invertebrate species. Among this large number of reef-associated species, however, only a small percentage is of major commercial importance (including snappers, groupers, parrotfish, lobsters, and conch). Among the species of recreational importance that are associated with seagrass and mangroves are snook (*Centropomus sp*.), tarpon (*Megalops atlanticus*), and bonefish (*Albula vulpes).*

A number of reef fish species form spawning aggregations, which are heavily fished. Intensive fishing of these aggregations have caused declines and in some cases localized extirpations of the spawning populations throughout the Caribbean (Sadovy 1994). Coral reefs are one of the region's greatest tourist attractions, and support vibrant dive tourism.

- ***Coastal lagoons***

Because the tidal range in the Caribbean is small and with highly variable hydrology, coastal lagoons play a key role in regulating coastal productivity and are favorable habitats for primary producers (phytoplankton and aquatic plants). Lankford (1977) defined a coastal lagoon as a coastal zone depression below mean high water, having permanent or ephemeral communication with the sea, but protected from the sea by some type of barrier. Nutrients are introduced into coastal lagoons from surface and groundwater flows as well as through exchange with the ocean. This promotes rates of primary and secondary production that are among the highest measured for natural ecosystems. Coastal lagoons and estuaries are the sites of interactions between freshwater discharge and the sea, which makes them very vulnerable to impacts originating in adjacent river basins.

Coastal lagoons consist of a high diversity of habitat types and primary producers (i.e., marsh grasses, mangroves, sea grasses, macro algae, benthic and epiphytic algae, and phytoplankton) that are sources of organic matter. Estuaries and coastal lagoons play a critical role in the life cycle of numerous finfish and shellfish species in the Caribbean. Two dominant types of habitats within coastal lagoons are seagrass beds and mangroves, which are described separately below.

- ***Seagrass beds***

Seagrass beds form complex physical structures and are a highly productive ecosystem, which enables them to support a considerable biomass and diversity of associated species. They grow in reef lagoons between beaches and coral reefs or form extensive meadows in more protected bays and estuaries. Of the seven species of seagrass recognized in the Caribbean, the two main species are the turtle grass (*Thalassia testudinum*) and the manatee grass (*Syringodium filiforme*). Seagrass beds serve as nursery grounds for the juveniles of many commercially important species, such as snappers, grunts, lobsters, and conchs. Seagrasses filter out sediments, stabilize the bottom sediments, and help to absorb excess nutrients from land run-off. Thus they play an important role in maintaining the health of adjacent coral reefs. The seagrass habitat attracts various species of fish, conch, lobster, turtles, sea urchins, and manatees for feeding and as nursery grounds.

- ***Mangroves***

Mangrove forests are an essential component of tropical coastlines. The common mangrove genera found in the Caribbean are *Rizophora*, *Avicennia*, *Laguncularia*, and *Conocarpus*, with the four dominant species being red mangrove (*Rhizophora mangle)*, black mangrove (*Avicennia germinans)*, white mangrove (*Laguncularia racemosa)* and the buttonwood *Conocarpus erectus. Other* species such as *Avicennia bicolor, Pelliciera* *rhizophorae, Rhizophora harrisonii* and *Rhizophora racemosa* are found in a few countries only, mainly in Central America (FAO 2007). Factors such as climate, salt tolerance, water level fluctuation, nutrient runoff, temperature, and wave energy influence the composition, distribution, and extent of mangrove communities. The mix of species may also be influenced by other factors such as predation of plant seedlings by crabs.

Mangrove forests are among the world's most productive ecosystems and are key to major food webs in coastal areas. Mangroves, epiphytic algae, bacteria, and other microorganisms, as well a wide variety of invertebrates take up and sequester nutrients in their tissues. When this living material dies and is decomposed, it is distributed by tidal flushing to areas where other organisms may utilize it.

Mangroves also provide nursery grounds and refuge for commercially important marine fish and invertebrates, act as buffers against hurricanes and tidal surges, and filter terrestrial sediment, pollutants, and nutrients, acting as sinks for these materials and minimizing their input into more sensitive habitats such as seagrass beds and coral reefs. Mangroves strongly influence the community structure of fish on neighbouring coral reefs. The biomass of several commercially important species is more than doubled when adult habitat is connected to mangroves. Current rates of mangrove deforestation are likely to have severe deleterious consequences for the ecosystem function, fisheries productivity, and resilience of coral reefs (Mumby et al 2004), as is increasingly taking place in the region.

The transboundary importance of the region's mangrove forests extends beyond the borders of the Caribbean Sea LME. These forests serve as over-wintering habitat for a number of species of neo-tropical migrant birds, whose populations could be threatened should these important habitats be lost.

- ***Beaches***

Beaches are deposits of sand between the high- and low-tide marks along the coastline. The sand can be calcareous (derived from the broken skeletons of corals, calcareous algae, molluscs, and echinoderms) or siliceous (derived from eroded rocks). Calcareous algae such as *Halimeda* sp., which also are found among seagrasses, are believed to be the major source of the white sand found on the beaches in some countries (e.g. Antigua and Barbuda). Beaches are dynamic, constantly experiencing deposition (accretion) or loss (erosion) of material, which is controlled by a number of agents including storms, offshore reefs, sand shoals, and currents. The stability of a beach, whether eroding or accreting, depends on a balance, over time, between the supply of sand and the rate at which it is transported away. Beach and dune sands serve as one of the world's major sources of construction aggregate. Noncalcareous sand is also used to produce minerals and ores for various industries, including electronics. Caribbean beaches are of great importance to tourism, attracting foreign visitors and local people throughout the region.

Beaches are also important nesting habitats for sea turtles. Each year, thousands of turtles make their way to beach nesting sites in the region to deposit their eggs above the high-tide mark. While this can create conflicts between recreational uses of beaches and their contribution to the biodiversity of the Wider Caribbean Sea ecosystem, it can also provide income, community employment, and educational opportunities through well-managed eco-tourism (CARSEA 2007).

- ***Deep water reefs and rocky outcrops***

The Caribbean Sea includes large expanses of deep water reefs and outcrops that harbour a wide variety of deep-sea corals (stony corals, gorgonians, soft corals, stylasterids, black corals, lithotelestid coral and sea pens) and commercially important fish species (Lutz and Ginsberg 2007). The distribution of deep water corals generally follows the Antilles and continental shelves of Central, South, and North America. Santa Marta Bank, Colombia is described as a deep water coral bank on the northwestern shelf of Colombia at a depth of 200 m (Reyes et al. 2005). Dawson (2002) reported that the greatest diversity of deep water stony coral species occurs at depths around 200-350 m, and the highest diversity of species is located around the northern islands of the Lesser Antilles.

Two of the more significant deep-sea coral species are *Lophelia pertusa and Oculina varicosa*. These species form extensive deep-water communities that harbour commercially important fish species, making them susceptible to destructive bottom trawling practices (Reed 2002). Among deep water habitats are the unique and vulnerable deepwater coral (*Oculina*) habitats found in the Caribbean and off the southeastern USA (Lutz and Ginsburg 2007, Ross and Nizinski 2007), which have been identified as essential fish habitat for Federally managed species in the USA. Although the existence of some of these deep-sea coral thickets has been known for several centuries, scientists know little about their distribution, biology, behavior, and function as essential habitats for fishes and invertebrates. Deep-water corals also provide crucial habitat and reproductive grounds for commercially important fisheries including sea bass, snapper, porgy, rock shrimp, and calico shrimp. A number of fishes have been observed or collected in association with deep coral habitats. While most of these are demersal species, certain commercially important pelagic species may also associate with deep-sea coral habitat. Swordfish (*Xiphias gladius*) have been encountered by submersibles visiting deep sea corals in Bahamian waters at 600 m (Harbison and Janssen 1987).

3.1.2. Reef ecosystem services

Marine ecosystems are prolific providers of ecosystem services. The Millennium Ecosystem Assessment (MA) defined four types of ecosystem services (Millennium Ecosystem Assessment 2005). It is common practice in economics to refer to goods and services separately and to include the two concepts under the term services. Although “goods,” “services,” and “cultural services” are often treated separately, the MA considers all these benefits together as “ecosystem services” because it is sometimes difficult to determine whether a benefit provided by an ecosystem is a “good” or a “service.” Also, cultural values and other intangible benefits are sometimes forgotten when referring to “ecosystem goods and services”. Although ecosystem services have been categorized in a number of different ways, for operational purposes, the MA classifies ecosystem services along functional lines, using categories of *provisioning*, *regulating*, *cultural*, and *supporting services*, and recognizes that some of these categories overlap. When assessing ecosystem services, it is often convenient to constrain the analysis spatially and temporally with reference to the ecosystem service or services being examined. Thus a river basin is often the most valuable ecosystem scale for examining changes in water services, while a particular agroecological zone may be more appropriate for assessing changes in crop production. When looking at interactions among services, the combination of services provided by an ecosystem, or the variety of services drawn on by a society, the question of boundaries becomes more complex (Millennium Ecosystem Assessment 2005).

The four types of ecosystem services defined by the MA, and adopted for this TDA, are:

Provisioning services: The products people obtain from ecosystems, such as food, fuel, fiber, fresh water, and genetic resources.

Regulating services: The benefits people obtain from the regulation of ecosystem processes, including air quality maintenance, climate regulation, erosion control, regulation of human diseases, water purification, and protection from extreme events such as storms and tidal surges.

Cultural services: The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.

Supporting services: Services that are necessary for the production of all other ecosystem services, such as primary production, production of oxygen, and soil formation.

Ecosystem services provided by the reef ecosystem are listed in Table 8 (adapted from UNEP (2005), CARSEA (2007), World Resources Institute (2009), and others.

Table 8. Ecosystem services provided by coastal ecosystems

ECOSYSTEMS	ECOSYSTEM SERVICES			
	Provisioning	**Regulating**	**Cultural**	**Supporting**
Coral reefs	• Food (fish and shellfish) • Ornamental fish and corals • Material such as seashells for use in handicraft • Construction material • Natural medicines and pharmaceutical products • Genetic resources	• Hydrodynamic barrier to wave energy (protection of shorelines from erosion, storms)	• Recreational and tourism value • Knowledge ystems and educational value • Spiritual and inspirational value	• Habitat for fish and shellfish • Material for the formation and maintenance of sandy beaches
Mangroves	• Food (fish and shellfish stocks) • Fuelwood • Construction material • Natural medicines and pharmaceutical products	• Stabilization of coastlines (buffer between land and sea) • Protection of adjacent coral reefs from suspended solids, pollutants and drastic changes in salinity due to inflow of freshwater • Removal of contaminants from surface inflows • Nutrient retention and removal • Protection from erosion and storm surges	• Recreational and tourism value • Knowledge systems educational value	• Habitats for a wide array of terrestrial and aquatic species • Feeding, nursery and breeding areas for fish and other species • Carbon sequestration (blue carbon) • Nutrients to other ecosystems such as coral reefs and seagrass beds

Seagrass beds	• Fish and shellfish • Natural medicines and pharmaceutical products	• Settlement and binding of suspended sediments and encouragement of accretion • Nutrient cycling • Reduction of wave energy	• Recreational and tourism value • Knowledge systems educational value	• Habitats for a wide array of aquatic species • Nursery and feeding areas and shelter for fish and crustaceans • Detritus to reef system • Food (detritus) to offshore habitats • Beach sand (from calcareous skeletons of organisms (e.g. molluscs, crustaceans, calcareous algae)
Beaches	• Construction material • Base for small-scale fisheries, tourism and recreational activities		• Recreational and tourism value • Knowledge systems educational value	• Habitats and nesting sites for fauna such as sea turtles • Coastline protection Stabilization of sediments

The importance of coral reefs to local economies is frequently underappreciated by government officials, coastal developers, and the wider population. One of the key barriers to better decision-making is lack of information and understanding of the scope and value of the benefits provided by marine ecosystems. Data gaps make it difficult to assess the economic impact of ecosystem services provided by coral reefs at the national level. A clear presentation of the magnitude of the economic values derived from coral reefs can provide support for appropriate policy, investment, and development decisions.

An attempt to address this gap was made by Burke and Maidens (2004), who estimated the annual value of services provided by Caribbean coral reefs at between US$3.1 billion and US$4.6 billion, with degradation by 2015 potentially costing between US$350 million and US$870 million per year. More recently, the Coastal Capital Project of the World Resources Institute (WRI) has developed a methodology to estimate the total economic value of three key coral reef-associated goods and services in the Caribbean for which it is feasible to develop realistic values—fisheries, tourism and recreation, and shoreline protection services (http://www.wri.org/project/valuation-caribbean-reefs). There has been some criticism of this approach, mainly based on the quality of data used. This underscores the need for improvement in data collection and availability in the region.

This method was piloted in Trinidad and Tobago and St. Lucia (Burke et al 2008), and was adapted for Belize to include the contribution of coastal mangroves (Cooper et al 2009), and for the Dominican Republic (Wielgus et al 2010). As shown in Table 9, in all three countries, the annual economic contribution of coral reef related tourism is several orders of magnitude (at least 10 times) greater than that of reef related fisheries. Similarly, the value of shoreline protection function exceeds the value of fisheries, and in Belize, this even exceeds the value of reef-related tourism. This analysis demonstrates that conservation of coral reefs (and coastal habitats in general) is a better economic alternative for the use of coastal resources (rather than their conversion to other uses that results in loss of their natural functions). The economic cost of coral reef habitat degradation in the CLME has been estimated by Burke and Maidens (2004).

Table 9. Annual economic contribution (million US$) of ecosystem services of coral reefs for Tobago and St. Lucia and coral reefs and mangroves for Belize

Ecosystem service	Tobago	St. Lucia	Belize
Coral Reef-associated Tourism and Recreation	$101- $130	$160- $194	$149.9 - $195.7
Coral Reef-associated Fisheries	$0.8 – $1.3	$0.5 – $0.8	$14.2 - $15.9
Shoreline Protection - Potentially Avoided Damages (annual value for 2007)	$18 -$33	$28 -$50	$231 – $347
TOTAL	**$119.8 -$164.3**	**$188.5- $244.8**	**$395 – $559**

The focus of the reef and pelagic ecosystem TDAs is on provisioning services related to living marine resources, in keeping with the goals of the CLME project. Living marine resources constitute the most important 'provisioning' service of the CLME. Throughout the region, there is high dependence on living marine resources for food and livelihoods, particularly from fishing and tourism. As such, the sustainability of its living marine resources is of considerable socio-economic importance to the countries. Fisheries and tourism contribute towards food security, poverty alleviation, employment, foreign exchange earnings, and the development of rural and coastal communities. Coral reef-associated tourism contributes substantially to the economy of the island nations.

3.1.3. Description of the current reef fisheries/mariculture and existing baseline

Caribbean fisheries are predominately dependent on nearshore coral reef ecosystems, which provide an important source of food, employment, and livelihoods for coastal communities. Reef organisms are also collected for the ornamental fish and live food fish trade. Mangroves and seagrass areas are also exploited for fish and invertebrates such as crabs, conch, shrimps, oysters, and mussels. Within the reef system (as defined in this TDA), the coral reefs are the most intensely exploited by large numbers of fishers. The majority of these are considered smallscale and artisanal, while a small proportion are industrial (commercial). For example, 90% of the fishers and 97% of the vessels in the Central American coutries are artisanal (FIINPESCA–OSPESCA/FAO/SUECIA 2009). It is assumed that the majority of the artisanal vessels and fishers are associated with the inshore reef fisheries, although many of them would exploit different species throughout the year.

Both the artisanal and industrial fisheries target high-value reef species, although a large diversity of species can be caught. Among the dominant reef resources are Caribbean spiny lobster (*Panulirus argus*), queen conch (*Eustrombus gigas*), and several species of snappers (Lutjanidae), groupers (Serranidae), and grunts (Haemulidae) (Figure 6). Although the landings (by weight) of reef species constitute a small fraction of the region's total landings, their economic value (particularly of lobster and conch) makes up a very substantial proportion of the value of the total landings (Figure 7). Reef fisheries are generally characterized by a high diversity of fish and invertebrate species, multiple gears (with major species and gear varying among the countries), diffuse landing sites, and strong multispecies and multigear interactions. Reef resources dominate the landings in many CLME countries and territories (e.g. Antigua and Barbuda, Bahamas, Belize, Honduras, Jamaica, Nicaragua, Panama, Puerto Rico and Turks and Caicos).

Despite their socio-economic importance, significant data and information gaps persist, even for the more valuable stocks that have been the subject of numerous studies (e.g. lobsters, conch, snappers, and groupers). In countries where the fisheries are primarily small-scale, data on fishing effort and landings are often inaccurate because of the widely dispersed nature of reef fisheries and the limited capacity of national authorities for monitoring and data collection. Estimation of fishing effort is also difficult because of the multi-species, multi-gear nature of the fisheries and the fact that most of the small-scale fishers are not usually registered. Much of the fisheries landings may be unreported and discards difficult to estimate.

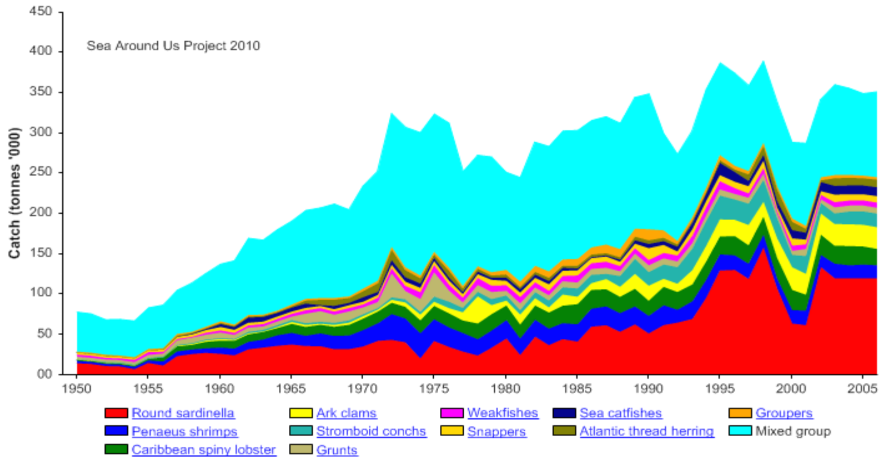


Figure 6. Reported landings by major species in the CLME.

Both reef and pelagic groups are included for comparison. Reef-related species are spiny lobster, conchs, grunts, snappers and groupers. The mixed group is likely to include a number of unidentified reef species (Sea Around Us 2010).

The fisheries for the major reef resources are described in the following.

- ***Spiny lobster***

Fisheries for lobster developed from smallscale operations in the early 1960s to fully overcapitalized, export-oriented industries in the 2000s. Landings of spiny lobster rose steadily to peak in 1999 at about 25.5 thousand tonnes valued at nearly US$220 million (Figures 6 and 7). The most important species captured in the Western Caribbean is *Panulirus argus*, followed by *P. guttatus*, and *P. laevicauda*. The spiny lobster supports one of the most economically important fisheries in the region, with the greatest stock abundances observed in the Western Caribbean as well as Brazil, as illustrated in Figure 8 (Ehrhardt et al, in press). In fact, in 2006, the spiny lobster accounted for nearly one-third the value of the total catch from this LME (Sea Around Us Project 2010). In the CLME, the greatest spiny lobster production comes from areas with large shallow coastal zones with suitable habitat for settlement of larvae and juvenile lobsters. The protection of shallow-water nursery habitats is therefore critical for sustaining viable lobster fisheries.

A range of fishing methods / gear types are used and include SCUBA, drop nets, trammel nets, spears, hooks, nooses, ‘casitas’, and collection by hand. No single country uses all gear types. Wooden bag nets and ‘casitas’, and use of ‘hookah’ and SCUBA are employed sequentially in the lobster fishery, with the artisanal fishers targeting the younger lobsters and the commercial fishers targeting the adult population. Historically, Cuba, the Bahamas, Nicaragua-Honduras, and Brazil have been the most important producers, in decreasing order (Ehrhardt et al, in press). This is changing rapidly as Nicaragua-Honduras and the Bahamas followed by Brazil are becoming the principal producers. The spiny lobster is the foundation of the Bahamas fishing industry, with about 7,000 tonnes caught in 2007 contributing US$70 million out of the US$80 million value of landings recorded during that year. In this country, spiny lobster, along with queen conch, is the most highly demanded commodity for export, with spiny lobster alone generating about 79% - 80% of this sector's revenue. High demand and reduced supply significantly increased lobster prices and have promoted further overcapitalization (Ehrhardt et al, in press). Major export markets include Canada, France, Germany, Japan, and USA.

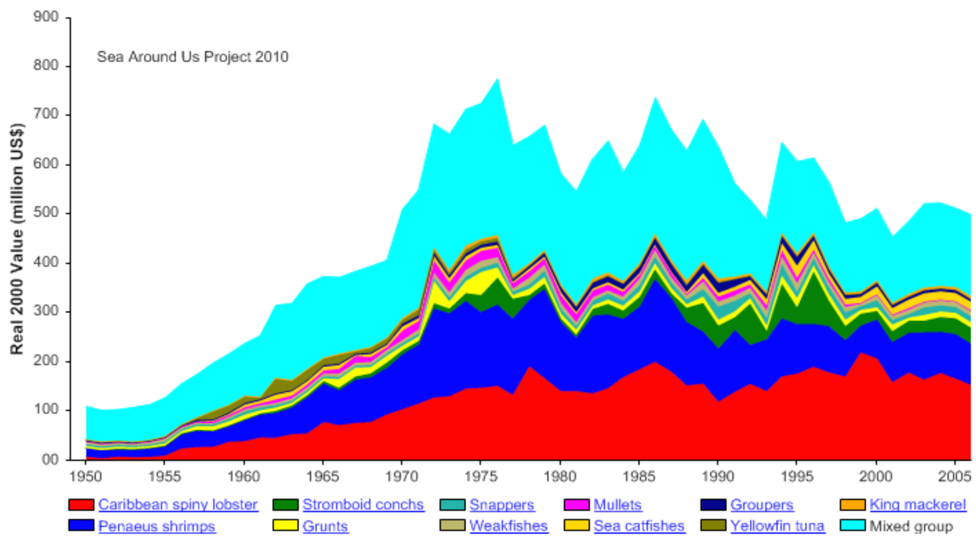


Figure 7. Value of reported landings by major species in the CLME

Both reef and pelagic groups are included for comparison (Sea Around Us 2010).

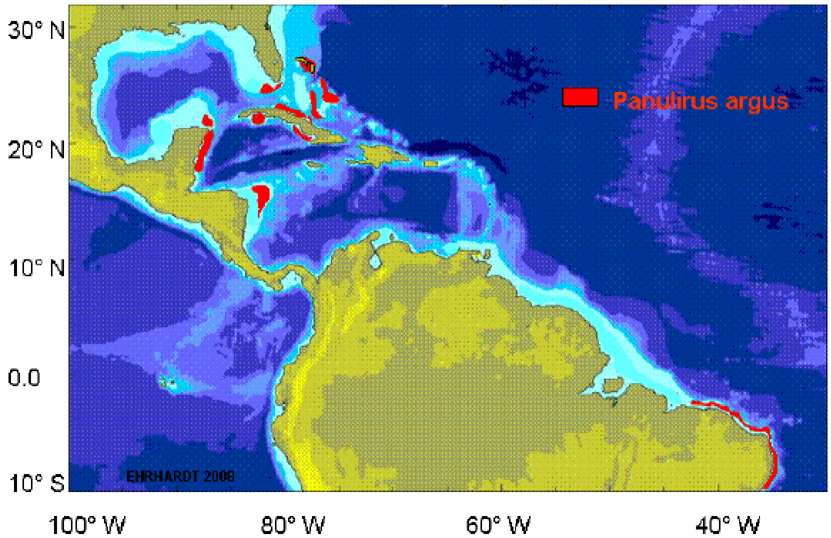


Figure 8. Geographical distribution of the main commercial spiny lobster fisheries in the Western Central Atlantic Ocean, including the CLME

Management of the lobster resource is unilaterally attempted in most countries with regulations on minimum size, spawning season closures, and no-take of berried females. Control of fishing capacities and landings are rare, however, and region-wide lack of enforcement and illegal fishing prevent sustainable utilization of the resource (Ehrhardt et al, in press). A sub-regional initiative to harmonize management of lobsters in Central America has been developed by OSPESCA (Organización del Sector Pesquero y Acuícola del Istmo Centroamericano).

The spiny lobster is of transboundary significance by virtue of planktonic larval dispersal. Long distance dispersal of lobster larvae in the Caribbean has been demonstrated (e.g. Silberman et al 1994). The Pan-Caribbean theory of spiny lobster population structure (Lyons 1980) is supported by genetic studies showing a lack of geographical differentiation in stocks of this species among Caribbean countries and an absence of seasonal variation in the genetic structure of postlarvae arriving at presumed "downstream areas" like the Florida Keys (Silberman et al 1994).

- ***Conch***

The conch species of highest commercial interest in the Western Central Atlantic are: *Eustrombus gigas* (queen conch), followed by *S. costatus*, *S. pugilis*, and *Melongena melongena*. Historically, the fishery for queen conch has been one of the most economically and culturally important in the Caribbean. In addition to its flesh, in Belize and Colombia this species also supports a small industry for pearls, which command a very high market price. The conch fishery is conducted throughout the CLME and consists of both industrial and artisanal fleets. The former operate primarily out of Jamaica, Honduras, Nicaragua, Colombia, and the Dominican Republic, with vessels fishing the outer shelves and offshore banks, particularly in the western Caribbean. Fishing is conducted primarily with SCUBA or the use of 'hookas', except in certain countries (e.g. Bahamas, Belize, Colombia, Martinique) where use of such gear is prohibited. In the Bahamas, the queen conch landings in 2007 were the second highest in terms of value (US$3 million) and third in terms of weight (379 tonnes) (FAO Fishery Country Profile).

In 1992 the queen conch was listed under Appendix II of CITES. Species listed in Appendix II are not in immediate danger of extinction but are threatened by international trade if it is not strictly controlled. CITES has since placed an embargo on queen conch exports from Honduras, Haiti, and the Dominican Republic, in an effort to promote sustainable trade in this species. In 1996, the International Queen Conch Initiative was established with the aim of improving regional management through harmonized regulations, enhanced communication and the application of scientific advice to management and assessments.

The queen conch has unique life history attributes that render this species particularly susceptible to habitat degradation and overfishing (Appeldoorn et al, in press). One of these is the tendency to aggregate in shallow areas for reproduction, where they are very vulnerable to capture. Newly settled juveniles spend much of their first year buried in soft sediments. In reef systems, settlement often takes place in back reef areas near channels through the reef, although larvae may also settle in deeper water. Juveniles begin to emerge from the area of settlement and take up an epibenthic existence in nearby seagrass beds (Sandt and Stoner 1993). These shallow coastal habitats are very critical for sustaining the populations and fishery for queen conch, as they are for lobsters.

The queen conch is a transboundary resource that may be widely dispersed in the larval phase and exploited by multiple countries. While observations indicate that the average extent of larval dispersal is in the range of tens to hundreds of kilometers, conch larvae have been found in the middle of the Eastern Caribbean and in the North Atlantic Drift (Appeldoorn et al, in press), indicating that some long-distance dispersal is possible. Despite this potential, empirical observations of larval distributions show that it is likely that dispersal is limited within sub-regions (e.g. Delgado et al 2008).

- ***Reef fish***

The most valuable reef fish fisheries are for snappers including queen snapper (*Etelis oculatus);* silk snapper (*Lutjanus vivanus*), blackfin snapper (*L. buccanella*), black snapper (*Apsilus dentatus*) and vermilion snapper (*Rhomboplites aurorubens*); and groupers including Nassau grouper (*Epinephelus striatus*), red grouper (*E. morio*), black grouper (*Mycteroperca bonaci*), yellowfin grouper (*M. venenosa*), and tiger grouper (*M. tigris*). Many snapper and grouper species have a wide depth range and the same species may be exploited in both shallow and deep waters. In some countries, reef fish are targeted when the seasonal, migratory pelagic species are unavailable.

A large variety of other reef fish species are caught, including reef-associated species of pelagic sharks and other pelagic fish such as barracudas (Sphyraenidae), sierras (Scombridae), and jacks (Carangidae). The most valuable species such as snappers and groupers are top predators on the reefs. As the populations of these groups are declining from heavy fishing, a number of other species including herbivores such as parrotfish are increasingly being targeted in some countries. This has serious implications for the health of coral reefs.

While reef fisheries are conducted throughout the CLME, they are not homogenous among the countries. Great variation exists, for example, in the proportion of artisanal and industrial fishing, gear types, and species targeted. Although larger and more mechanized (industrial) vessels enter the fishery, reef fisheries remain predominantly coastal and small-scale, and conducted by numerous artisanal fishers. The same species may be targeted by both artisanal and industrial fisheries. For example, in the Colombian archipelago (San Andrés, Providencia and Santa Catalina) queen and silk snappers are exploited in the industrial fishery using '*palangre de fondo*' or bottom longlines, and in the artisanal fishery using *'Reel'* ('*palangre vertical de fondo*', or vertical bottom longlines). Both the industrial and artisanal sectors of Colombia exploit groupers in deep waters. In the Colombian archipelago, the most common industrial captures are coral reef fish species such as snappers and groupers, including *L. vivannus*, *Apsilus dentatus*, *Etelis oculatus*, *Lutjanus buccanella*, *Mycteroperca venenosa*, *M. intersticialis*, *Epinephelus guttatus* and *E. adcensionis* (Caldas 2005). Other countries such as Jamaica have an interest in parrotfish in addition to other reef fish. Live bait fishing is conducted for reef-associated pelagic species such as barracuda (*Sphyraena barracuda*) and wahoo (*Acanthocybium solandri*).

Deep sea fishing for reef fish occurs to depths greater than 100 m in the USA Caribbean and other areas such as off the continental shelf in the southern Caribbean. The deep slope and bank fisheries are carried out by a number of countries (e.g. the USA off Puerto Rico, Venezuela, Barbados, Colombia, St. Lucia, Jamaica, and the French West Indies). Deep water reef fishing is mainly focused on deep water snapper and grouper and includes commercial and recreational fishing. Gear utilized in commercial deep water snapper and grouper fishing includes vertical set line, bottom longline, handlines, electric or hydraulic reels, and traps.

Reef species such as snappers and groupers are generally slow growing and long-lived, with high ages of maturity and low natural mortality rates (Manooch 1987). Moreover, most large Caribbean reef fish species form transient spawning aggregations at specific times and locations such as off the shelf edge and outer edges of reefs (Kobara and Heyman 2007). The single greatest threat to spawning aggregations is from fishing, with a number of aggregations extirpated throughout the region. These factors, combined with considerable variation in larval recruitment, make reef fish highly susceptible to overfishing and slow to recover from population collapse.

- ***Marine turtles***

Other animals found in the reef complex are six species of marine turtles that nest throughout the region. All sea turtle species are considered Endangered or Critically Endangered. Sea turtles are fully protected from harvest by more than half of all Caribbean governments (Dow et al 2007), many of which are also Parties to regional and international environmental agreements (e.g., CITES, IAC, SPAW) that protect sea turtles. All marine turtle species occurring in the WCR have been included in CITES Appendix I since 1977 and the Caribbean population of the Hawksbill Turtle has been listed in CITES Appendix I since 1975. Although long valued for their parts and products, the importance of ecological interactions of sea turtles within marine ecosystems has only recently been recognized.

Despite their protected status, in some countries turtles are fished on an occasional and opportunistic basis, while in others they are specifically targeted and generate significant income. In a number of countries important exemptions to otherwise complete legal protection exist, for example, for the extraction of eggs (Guatemala), of turtles for indigenous use (Honduras), and turtles for subsistence use (Colombia) (Bräutigam and Eckert 2006). The exploitation and subsistence consumption of the green turtle is an ancient tradition in Central America, where turtle eggs and meat are not only important in terms of nutrition, but also play an important role in the coastal communities in which turtle hunting (*tortuguear*) is a lifestyle and culture beyond protein supply. Although turtle eggs are more widely protected by law in the WCR than turtles themselves, the collection of eggs is intensive and pervasive throughout the region and especially in Central America. In Guatemala, for example, there is concern that virtually every egg laid in the country is collected for human consumption (Bräutigam and Eckert 2006). Hawksbill shell is used in gold and silver jewelry and other ornamental objects that have a high demand in national and international markets. Throughout the region, turtles also form the basis of important ecotourism initiatives, such as at Tortuguero and Gandoca in Costa Rica and at Matura and Grande Riviere in Trinidad, which provide substantial economic benefits to local communities.

Official statistics is limited on the levels of exploitation of marine turtles in countries that allow their exploitation, as monitoring is either non-existent, sporadic, or fragmentary. Consequently, it is impossible to derive any credible estimate of the numbers of marine turtles taken at the regional level (Bräutigam and Eckert 2006). Fewer data exist on levels of exploitation of marine turtle eggs. Nevertheless, increasing data from tagging, satellite-tracking, and genetic analyses is documenting transboundary movements of marine turtles and delineating individual marine turtle stocks. These data unequivocally point to the need for coordinated effort in managing marine turtles that, for example, nest or forage in Bonaire, Barbados, or Costa Rica, where they are protected by law, and travel to other countries such as Dominica, Honduras, Nicaragua, and St. Vincent and the Grenadines where they are legally exploited (Bräutigam and Eckert 2006). In some instances, these contradictory management regimes impinge on non-extractive marine turtle initiatives.

Greater co-operation between the countries of the Caribbean is urgently needed to conserve marine turtle populations and the people who benefit from them. Significant progress has already been made in the area of regional co-operation with the coming into force of the SPAW Protocol in 2000 and the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC) in 2001 (Bräutigam and Eckert 2006). The Wider Caribbean Sea Turtle Conservation Network (WIDECAST), a scientific network affiliated with the Caribbean Environment Programme of the United Nations Environment Programme (UNEP), provides an operational mechanism for training, communication, collaborative research and the replication of successful programmes across more than 40 participating WCR States and territories.

Mariculture

As previously described, a number of CLME countries, notable the continental countries, have well-developed aquaculture sectors for shrimp and tilapia. Mariculture of reef species is limited and includes small scale production of seaweed (*Gracilaria*) in some of the islands, such as St. Lucia, which produced about one tonne of seaweeds in 2007 (FAO 2009). In Cuba, mariculture of shrimp (*Penaeus schmitti*) is carried out and the cultivation of marine fish (*Sparus aurata* and *Dicentrarchus labrax*) in cages at depths exceeding 20 m is in the experimental stage. In Colombia, there is experimental culture of cobia.

(Need info from other countries on culture of reef fish, if any)

3.2. Analysis of the current issues and their implications for the reef ecosystem

This section provides a brief overview of the major issues in reef ecosystems. These issues will be discussed in greater detail in subsequent sections. As previously discussed, the coastal habitats of the CLME are of enormous social and economic benefits to the countries and people of the region, as seen by the wide range of valuable ecosystem services they provide. Yet, these habitats and their living resources are experiencing unprecedented rates of degradation and loss, compromising their functioning and their ability to produce valuable ecosystem services on which thousands of people are dependent for livelihoods, income, and food security. The close connectivity among habitats and living marine resources within the CLME means that their degradation and loss in one area could have far-reaching effects in other areas and potentially throughout the entire ecosystem. Attempts have been made to address some of the problems through the establishment of MPAs.

The Reefs at Risk Threat Index developed by Burke and Maidens (2004) showed that about two-thirds of the region's reefs were threatened by human activities. A recent update of this assessment reveals that this proportion has increased to 75% (Burke et al 2011)[7]. As in the previous Reefs at Risk assessment, the updated assessment found that fishing is the most pervasive threat. Other threats include marine-based pollution, coastal development, and watershed-based pollution. These pressures work individually and synergistically to cause significant large-scale loss of coral cover and marine biodiversity.

[7] Burke et al. 2011. Reefs at Risk Revisited. World Resources Institute, Washington, DC.

Although some reefs have survived heavy overfishing, the combination of this threat with coral diseases, hurricanes, pollution, and coral bleaching has been devastating for countries such as Jamaica and for many areas in the Lesser Antilles (Burke et al 2011). Climate change has become a major pervasive force affecting the region's marine habitats, especially coral reefs. Increasing sea surface temperatures (SST) cause bleaching in corals, increasing acidification (as the concentration of carbon dioxide rises in sea water) dissolves or impairs formation of carbonate skeletons in corals and other calcareous organisms, and storms and hurricanes, which are predicted to become more frequent and intense with a warming climate, cause severe physical damage. Mangrove forests and seagrass beds are also vulnerable to the impacts of climate change.

Mangrove and seagrass habitats are increasingly being converted to other uses such as urban and tourism infrastructure and aquaculture ponds. Not only would the loss of mangrove and seagrass beds affect the health of coral reefs and of species that are dependent on them for feeding and nursery areas, but would also increase the exposure of coastal communities to extreme meteorological phenomena and of coastlines to greater erosion by wave action and storm surges. The latter is of growing concern in the region in view of the expected increase in frequency and intensity of storms and hurricanes arising from a warming climate.

Throughout the region, reef fish has been heavily exploited, especially in nearshore areas. As a result of intense historical exploitation, the trend over the past few decades has been of declining catch accompanied by changes in fish communities towards smaller, low valued species. The life history strategy of many reef fish (e.g. long-lived, slow growth rate, high age at maturity), makes them highly susceptible to overfishing and slow to recover from population collapse (Manooch 1987). A number of reef fisheries have already collapsed and some populations, including fish spawning aggregations of valuable reef fish, have even become locally extinct.

Also alarming is the decrease of herbivorous fish such as parrotfish in many reef areas, which has contributed to regime shifts from coral to algal dominated reef habitats that is becoming widespread in the CLME. Depletion of herbivores limits the recovery of reefs, for example, from damage caused by coral bleaching that causes corals to be even more susceptible to algal overgrowth. As mentioned, in the Caribbean there is high connectivity among habitats and species, which is important for maintaining fish populations and building resilience of coral reefs to external perturbations, including to climate change impacts. These factors must be taken into consideration in the development of management strategies, such as design of protected areas and no take reserves.

As nearshore habitats and resources are degraded and depleted, exploitation is shifting towards offshore areas. In the absence of appropriate management interventions to recover inshore habitats and living marine resources and protect those in offshore areas, these negative trends are likely to continue. These pressures on the region's habitats are expected to increase with growing population and tourism that will increase demands for space, natural resources, and infrastructure. Greater amount of waste production and disposal in the marine environment would also be expected if measures are not implemented to address these issues.

Regional and international management frameworks relevant to reef habitats and associated fisheries exist, such as the SPAW Protocol, Convention on Biological Diversity (CBD), CITES, and FAO Code of Conduct for Responsible Fishing, which many CLME countries have ratified and adopted. In addition, many Caribbean countries have established MPAs, and there are currently 280 MPA sites in the CLME registered on the Marine Protected Areas Global Database (http://www.mpaglobal.org/). Yet, degradation and loss of these habitats and fish stock depletion continue because of poor implementation and enforcement at national and regional levels, among other factors. This is demonstrated by the low proportion (14%) of MPAs that are determined to have partially or fully effective management.The lack of adequate data and information across the scale of the CLME compounds the issues related to proper management of the region's transboundary resources. There is need for countries to share information that has been collected in a harmonized manner.

The priority issues identified in the preliminary TDAs were: unsustainable exploitation of fish and other living marine resources, habitat degradation and community modification, and pollution. More recent analyses have reinforced these findings and confirmed the continuing importance of these three issues in the region (e.g. Brown et al 2007, CARSEA 2007, Heileman and Mahon 2008).

3.2.1. Unsustainable exploitation of reef living resources

Fisheries overexploitation has been assessed as severe in the Caribbean Sea (UNEP 2004a, 2004b, 2006). Unsustainable exploitation of living marine resources is of major transboundary significance owing to the shared and/or migratory nature of some of these species, including those of commercial importance. As previously mentioned, reef fish and invertebrate resources are likely to be shared by virtue of planktonic larval dispersal and/or exploitation of the same stocks by multiple countries. Overfishing is rated as the most pervasive threat to the region's reefs, affecting almost 70% of reefs; in reality this could be even higher (Burke et al 2011). Declines in catch per unit effort (CPUE), reduction in the size of fish caught, and changes in species composition are all indications of unsustainable exploitation in the region. Not only have unsustainable exploitation affected reef fish, but it has also contributed to declines in abundance of other species such as turtles.

The major environmental impacts of unsustainable exploitation include:

i. Reduced abundance of stocks (as evident in decreasing total catches and catch per unit effort and collapsed stocks);

ii. Change in trophic structure of fish populations, with a trend towards small, low trophic level species;

iii. Threats to biodiversity;

iv. Degradation of habitats.

Reduced abundance of stocks

Overfishing has affected almost all areas in the Caribbean, where the reefs have some of the lowest recorded fish biomass measures in the world (Burke et al 2011). Fishing on Caribbean reefs has returned increasingly diminished yields as human populations have escalated in the region. Since the mid-1970s, annual reported landings of CLME reef resources in the Sea Around Us database have showed a general declining trend (Figure 9), although there have been some small increases over the past few years (probably attributable to expansion of fisheries into new fishing grounds).

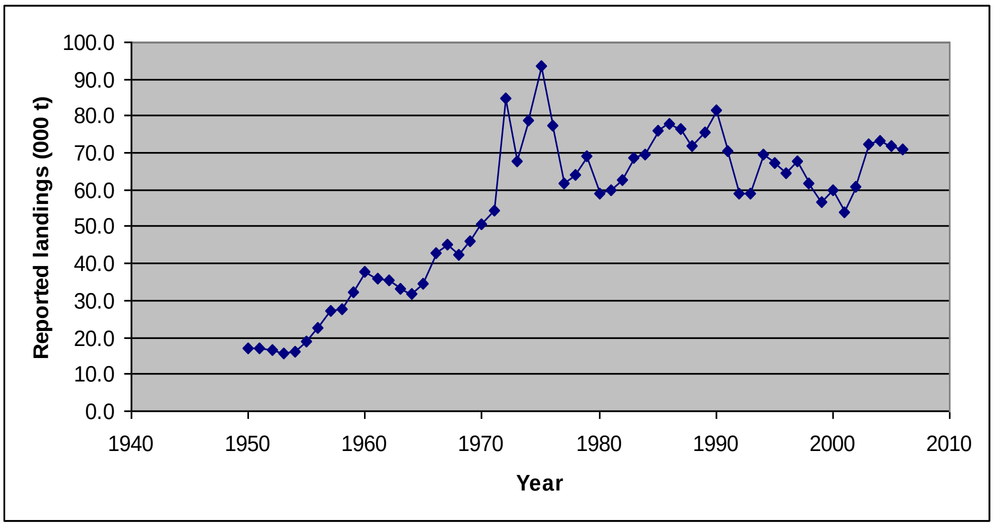


Figure 9. Annual reported landings of reef resources in the CLME

All the major reef fishery resources of the CLME (spiny lobsters, conch, snappers, and groupers) are overexploited or exploited close to their maximum sustainable yield (MSY) (FAO 2001a, 2001b; Mahon 2002). This is revealed by the general declines in reported landings of these species (Figure 10), based on data from the Sea Around Us Project (2010).

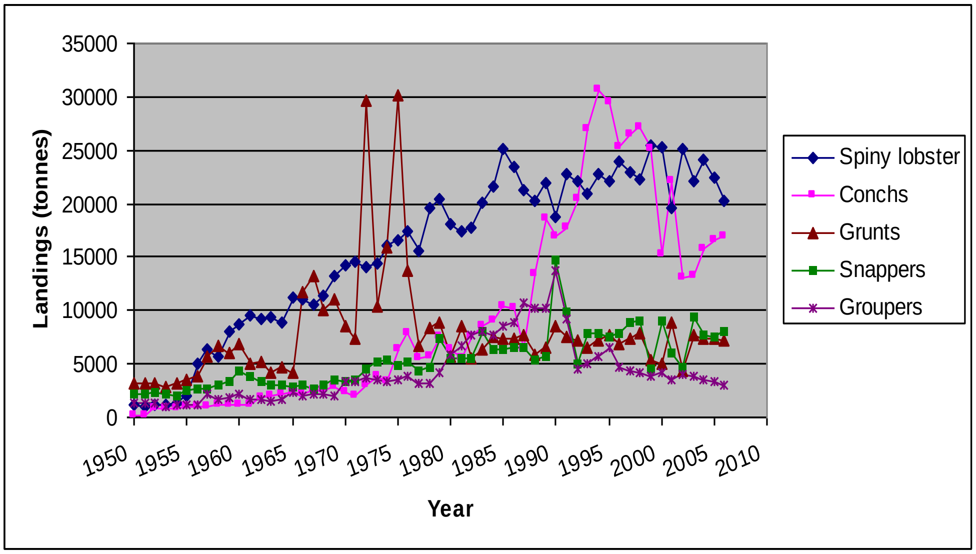


Figure 10. Trends in annual catches of major reef associated resources in the CLME from 1950 – 2006

The spiny lobster resource is being fully or overexploited throughout much of its range (FAO 2001a, 2001b), although there were insufficient data from some areas to reliably estimate the status of this species. The overexploited status has resulted from high fishing pressure and the catching of undersized lobsters and berried females, although habitat degradation is also thought to have contributed (Ehrhardt et al, in press). At the Second Workshop on the Management of Caribbean Spiny Lobster Fisheries in the Western Central Atlantic Fisheries Commission (WECAFC) Area (FAO 2002), a number of countries reported similar trends in the status of the spiny lobster within their waters. For instance, in the Bahamas, decline in landings, abundance and in mean size, and steadily increasing fishing mortality were reported. Cuba also reported a decline in landings, abundance, and in recruitment over the past decade, thought to have resulted from a combination of fishing and unfavourable environmental conditions. In the Dominican Republic, there has been a decline in the size captured, which is below the legal minimum size. Fishing effort for spiny lobster has increased significantly over recent years in Jamaica, and the present level of fishing mortality appears to be greater than the optimum recommended for the fishery. Nevertheless, a more recent assessment of the industrial fishery on the Pedro Bank of Jamaica, the lobster was reportedly not overfished at the current level of catches (CRFM 2009).

Queen conch populations in a several countries are partially, fully, or severely overfished. Recent assessment of queen conch status in St. Lucia showed this species to be overfished in this country’s waters, with the CPUE continuing to decline (CRFM 2009). Overfishing of conch, fuelled primarily by international demand for meat and conch pearls, has reduced most stocks throughout the region and has resulted in declining annual harvests (Appeldoorn et al, in press). According to the Sea Around Us project (2010) landings of conch rose steadily from 1950 to peak in 1994 at about 31,000 tonnes, following which it declined to about 13,000 tonnes in 2002 and thereafter increased slightly to about 17,000 tonnes in 2006 (Figure 10). The value peaked in 1996 at nearly US$107 million, declining to about US$33 million in 2006. As previously discussed, the conch fishery has been overexploited to the point where it warranted international action by CITES.

Other species whose populations have significantly declined in the CLME include marine turtles. According to the IUCN Red List of Threatened Species, persistent over-exploitation, especially of adult females on nesting beaches and the widespread collection of eggs are largely responsible for the depleted status of all six Caribbean sea turtle species. Turtles are accidentally captured including as by-catch in active or abandoned fishing gear, and exploited by hunting/poaching. In a review of exploitation, trade and management of sea turtles in the WCR by Bräutigam and Eckert (2006), it was found that notwithstanding documented examples of apparently increasing or recovering populations, marine turtle populations throughout the WCR are so severely reduced from historical levels as to be considered to be "virtually extinct" by Bjorndal and Jackson (2003) in terms of their role in Caribbean marine ecosystems. The current hawksbill populations in the Caribbean have been reduced to only about 10% of pre-Columbian levels (León and Bjorndal 2002). Some of the world's previously known largest marine turtle breeding colonies, including those of the green turtle in the Cayman Islands, have almost vanished. Nesting trends for green turtles elsewhere in the WCR are mixed, with rising trends at Tortuguero (Costa Rica), currently the region's largest colony, as well as in the USA and Mexico, but long-term declines at Aves Island (Venezuela), once a globally significant site. In the Yucatán Peninsula (Mexico), hawksbill nests counted in 2004 amounted to only 37% of those recorded in 1999 (Abreu Grobois et al. 2005). Protection of turtles only in some countries is obviously not sufficient to protect these animals. There are numerous examples of marine turtles tagged at protected nesting sites, only to be killed in foraging grounds during open seasons in other countries. For example, tagging studies show that the waters of Nicaragua are the principal feeding grounds for the Tortuguero nesting colony of green turtles. More than 11,000 green turtles are estimated to be taken annually in the legal fishery operating on the Caribbean coast of Nicaragua.

During the 1980s and 1990s, the region experienced notable changes in the relative abundance of reef fish species. This is confirmed by informal reports from fishing communities about declines in overall catch per trip, reduction in individual sizes of fish caught, and changes in species composition of the catch (Mahon 1990, 1993). Recent analyses have shown continuing changes in reef fish biomass. For example, Paddack et al (2009) found that overall reef fish density has been declining significantly for more than a decade, at rates that are consistent across all sub-regions of the Caribbean basin (2.7% to 6.0% loss per year) and in three of six trophic groups. However, the declines across a wide range of species, including lower trophic levels and smaller-bodied species not targeted by fisheries, suggest that they are not due to fishing pressure alone.

Of particular concern is the overfishing of spawning aggregations of reef fish, given their high vulnerability to overfishing and the importance of these aggregations for the maintenance of reef fish populations. While these aggregations usually consist of a single species, several sites harbour aggregations of mixed species. In Belize, for example, several sites that harbour Nassau grouper (*Epinephelus striatus*) also contain aggregations of other species. Sala et al. (2001) documented an aggregation of *E. striatus*, but reported that black grouper (*Mycteroperca bonaci*), yellowfin grouper (*M. venenosa*), and tiger grouper (*M. tigris*) also aggregate to spawn at the same location at nearly the same time. Claro and Lindeman (2003) provided a comprehensive set of examples of sites from Cuba that harbour several grouper and snapper species. These fish migrate long distances to aggregate for spawning at or near the shelf edges and fore reef.

Many exploited spawning aggregations have been severely reduced or destroyed due to increased numbers of fishers, improved technology, limited understanding of their ecological importance, and inappropriate management practices (Sadovy 1994). By far the most significant threat to the persistence of healthy spawning aggregations is fishing directly on the aggregation, but also along migration routes to and from the aggregation, and with the use of destructive fishing methods or heavy fishing, at times and locations away from the aggregation sites. In the Colombian archipelago, heavy fishing has significantly reduced grouper spawning aggregations to less than one-third of their previous levels (Prada et al. 2004).

Of the known aggregating reef fish species, the Nassau grouper is among the best studied in the region. This species has been heavily exploited, with declines and even commercial extinction in a number of localities including in the Bahamas, Cayman Island, Cuba, Dominican Republic, Puerto Rico, and the British and US Virgin Islands (Sadovy and Eklund 1999). Box 5 gives specific examples of spawning aggregations of Nassau grouper that have been extirpated. Other grouper species appear to be showing similar declines. These trends are common throughout the Caribbean, where many known grouper spawning aggregations have been fished to near extinction.

Overfishing of Nassau grouper is of transboundary importance since there may be a high gene flow in the region and larval dispersal over great distances (Hateley 1994, cited in Sadovy and Eklund 1999). There is no evidence of distinct subpopulations of Nassau grouper based on genetic work on fish sampled from a number of sites in Florida, Cuba, Belize, and the Bahamas (Sedberry et al 1996). Individuals may migrate over long distances to the spawning grounds (Sadovy and Eklund 1999).

Larval connectivity, including from spawning aggregations, is important for the resilience of reef fish populations. Spawning aggregation sites are critical for the maintenance of reef fish populations (Heyman et al 2008). Scientific evidence suggests that spawning locations may function to retain larvae in which case spawning aggregations should be managed as separate stocks (Grober-Dunsmore and Keller 2008). These sites should form an important component of marine reserve networks.

Box 5. **Examples of Caribbean spawning aggregations of the Nassau grouper *Epinephelus striatus* fished to extirpation**

- In the western Atlantic, a minimum of 10 of 50, and possibly considerably more (definitive information is lacking), known aggregations have been reportedly destroyed by over-fishing*.
- In Belize, the aggregation at Emily Caye Glory that was reported to have produced two tonnes per day in the late 1960s maintained only 21 individuals in the peak of the 2001 spawning time for this species. *S*pawning aggregations of this species have also been eliminated at Rise and Fall Bank, and Mexico Rocks*
- *S*pawning aggregations have also been eliminated at Majual on the Yucatan coast of Mexico*.
- An aggregation in Guanaja, Honduras, was destroyed by fishermen in only three years after its discovery*.
- In Puerto Rico, this grouper fishery had collapsed by the late 1980s*.
- Recent surveys in the Bahamas have shown that this species, which may travel up to 110 km to a FSAS at High Cay, have been heavily exploited by fishing; aggregations no longer occur, except for a few fish scattered in shallow water*.
- The Cayman Islands is one of only a few countries that still have active Nassau grouper spawning aggregations. Previous studies have documented five historical and existing Nassau grouper spawning aggregation sites in the Cayman Islands; three of these sites are inactive or commercially extinct (Whaylen et al. 2004).

Annual trends (from 1950 to 2006) in the overall status of reef resources in the CLME are represented by the Stock Status Plots (SSP)[8] (Figure 11). These plots assess the status of stocks by number of stocks (top) and by catch biomass (3-year running average values; bottom) since 1950 (Sea Around Us Project 2011). Stock-status categories are defined using the following criteria (all referring to the maximum catch [peak catch] or post-peak minimum in each series): *Developing* (catches ≤ 50% of peak and year is pre-peak, or year of peak is final year of the time series); *Exploited* (catches ≥ 50% of peak catches); *Over-exploited* (catches between 50% and 10% of peak and year is post-peak***);*** *Collapsed* (catches < 10% of peak and year is post-peak); and *Recovering* (catches between 10% and 50% of peak and year is after post-peak minimum). *Note that (n), the number of 'stocks' is defined as a **time series** of a given species, genus or family (higher and pooled groups have been excluded) for which the first and last reported landings are at least 10 years apart, for which there are at least 5 years of consecutive catches and for which the catch in a given area is at least 1,000 tonnes.The SSPs are an ecosystem-based tool for evaluation of catch data and the results for individual 'stocks' must be interpreted with caution.*

[8]The stock status analyses for reef and pelagic stocks were carried out for the CLME project by D. Zeller and K. Kleisner of the University of British Colombia Sea Around Us Project.

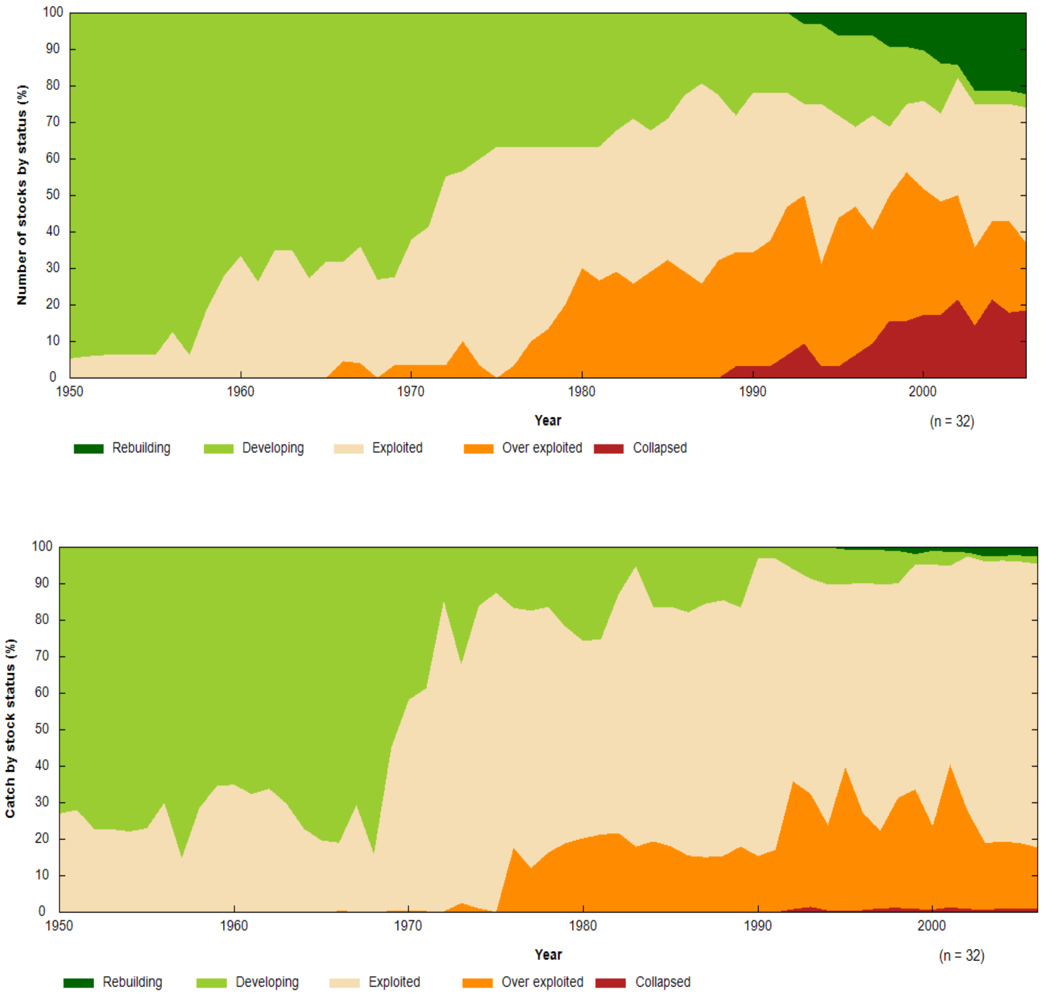


Figure 11. Stock Status Plots for reef fish in the CLME

As can be seen in the top panel in Figure 11, the number of overexploited stocks increased markedly from the mid-1970s and the number of collapsed stocks from the late 1980s, with both generally stabilizing in recent years (although the fluctuations continued). In 2006, about 75% of the commercially exploited reef fish stocks were either exploited (40%), overexploited (about 20%) or had collapsed (nearly 20%), with the rest rebuilding (Figure 11, top). Slightly less than 20% of the catch in 2006 came from overexploited stocks (decreasing from about 40% in 2002), with negligible catches from collapsed, developing or rebuilding stocks (Figure 11, bottom). These trends confirm the widespread reports of overexploited and collapsed stocks in the CLME, and are consistent with the unregulated expansion of fishing in earlier decades. The results of these analyses are very useful in providing a holistic picture of the status of the reef resources and conveying strong messages to policy makers about the need to reverse or prevent further declines before they become irreversible. This is of particular concern for large bodied reef fish species, which are highly vulnerable to fishing pressure because of their life history strategies.

Change in trophic structure of fish catch

An indicator of the ecosystem impacts of unsustainable fishing practices is a change in the structure of the marine food web, as reflected in changes in the mean trophic level (TL) of the catch. This phenomenon - 'fishing down the food web'- occurs with depletion of large predators (high trophic level species) through fishing, leading to a predominance of smaller, low-trophic level species (Pauly et al. 1998). Overfishing occurs on virtually every reef in the Caribbean, with larger groupers and snappers rare throughout the region (Burke et al 2011). Reduced abundance of large-sized carnivorous reef fish such as snappers and groupers was observed in several locations (e.g. in the Bahamas, Grand Cayman, Cuba, and St. Vincent) surveyed during the Atlantic and Gulf Rapid Reef Assessment (AGRRA) programme (Kramer 2003). Similarly, in the Colombian archipelago, there has been a shift in species composition with reef fish landings, once comprised mainly of snappers and groupers, now dominated by pelagic fishes that account for more than 70% while groupers and snappers remain high (10% of the total fish landings) only at remote reefs (Prada et al 2007).

Complete disappearance of several large predatory reef fishes in the Caribbean indicates ecological and local extinctions have occurred in some densely populated areas in the region. This is consistent with the observed global trend of reduction in large predators (Pauly et al 1998, Myers and Worm 2003). In February 2004, the Conference of the Parties to the CBD identified a number of indicators to monitor progress toward reaching the target to "achieve by 2010 a significant reduction in the current rate of biodiversity loss". The "Marine Trophic Index" (MTI) is one of the eight indicators that the Conference of the Parties of the CBD identified for "immediate testing" of their ability to measure progress towards the 2010 target. The MTI is the CBD's name for the mean trophic level of fisheries landings, originally used by Pauly et al. (1998) to demonstrate that fisheries, since 1950, are increasingly relying on the smaller, short-lived fish and on the invertebrates from the lower parts of both marine and freshwater food webs.

Analyses carried out by the UBC Sea Around Us Project for the CLME project showed that the MTI of the annual catches of reef fish declined steadily between 1950 and 2006 (Figure 12). These analyses relied upon the global database of fish landing assembled and maintained by the FAO. The observed decline in MTI could be attributed to the progressive depletion of top predatory reef fish such as snappers and groupers. Any decline in the mean TL of the fisheries catches should be matched by an ecologically appropriate increase in these catches, as shown by the FiB Index[9]. In the absence of geographic expansion or contraction of the fishery, and with an ecosystem that has maintained its structural integrity, moving down the food web should result in increased catches[10] (and conversely for increasing TL), with the FiB index remaining constant. The FiB index increases where geographic expansion of the fisheries is known to have occurred. As shown in Figure 12, the initial increasing trend in the FiB Index for the CLME reef

[9] This index has the property of increasing if catches increase faster than would be predicted by TL declines, and to decrease if increasing catches fail to compensate for a decrease in TL.

[10] As the lower trophic levels usually have a higher biomass, as seen in the classical trophic pyramid.

fisheries might have been caused by expansion of these fisheries. On the other hand, the FiB will decrease if discarding occurs that is not considered in the 'catches', or if the fisheries withdraws so much biomass from the ecosystem that its functioning is impaired (Sea Around Us Project 2010). The decline in the FiB Index for CLME reef fish, especially from the 1980s accompanied by a steady decrease in annual landings are alarming trends that reflect the impairment of ecosystem functioning of Caribbean reefs. These trends are consistent with those of the stock status trends in the previous section.

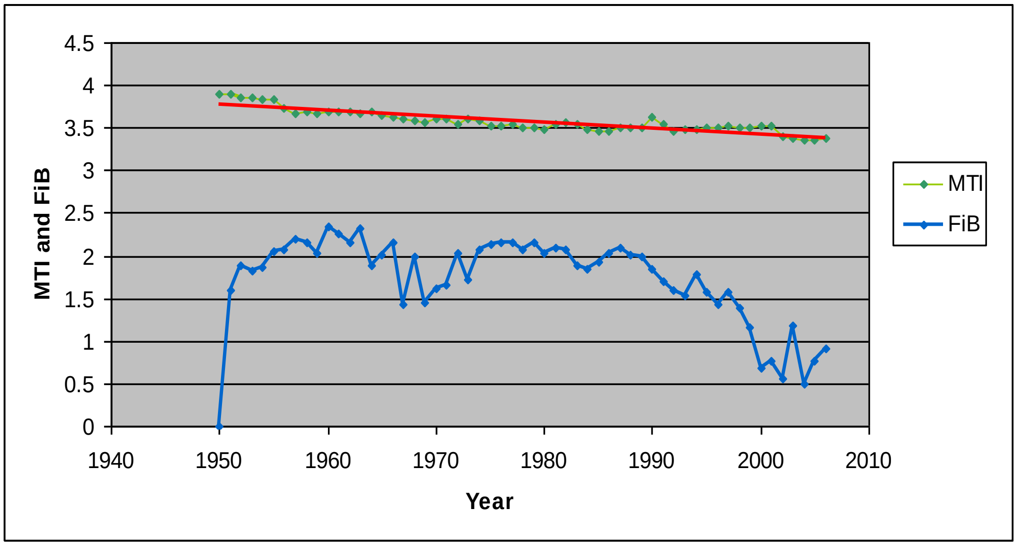


Figure 12. Marine Trophic Index (MTI) and Fishing-in-Balance Index (FiB) for reef species in the CLME

Declining biodiversity

Overfishing has been identified as the most pervasive threat to Caribbean coral reefs (Burke and Maidens 2004), and has been one of the major causes of the deterioration of reef condition in the Caribbean in recent years. Overfishing, particularly of herbivorous species, has been identified as a key-controlling agent on Caribbean reefs, leading to shifts in species dominance (Aronson and Precht 2000). One of the knowledge gaps identified in the previous TDAs was the impacts of habitat degradation and biodiversity loss on ecosystem services. Marine biodiversity loss is increasingly impairing the ocean's capacity to provide food, maintain water quality, and recover from perturbations (Worm et al 2006).

The status of biodiversity is reflected by the categories of IUCN status on the Red List. The Endangered status of green and loggerhead turtles means that these species meet a specific series of "listing criteria", including "an observed, estimated, inferred or suspected reduction of at least 50% over the last 10 years or three generations, whichever is the longer." Olive ridley turtles are classified as "Vulnerable". Leatherback, hawksbill and kemp'r Ridley turtles are classified as "Critically Endangered" (at a global scale), a crisis category reserved for species that, among other features, are characterized by having sustained "an observed, estimated, inferred or suspected reduction of at least 80% over the last 10 years or three generations, whichever is the longer".

Grouper and snapper populations have drastically declined in the Caribbean, with some species currently on the IUCN Red List. Nassau grouper populations have declined dramatically in the last 50 years and are now included on the IUCN Red List of Endangered Species (IUCN 2007), which is attributed to an estimated decline in population abundance of 40% within its distributional range. The Goliath grouper, *Epinephelus itajara* (previously called jewfish), is listed as critically endangered and face an extremely high risk of extinction in the wild. Yellowfin grouper has been placed on the IUCN Red List of Threatened Species. Cubera snapper is listed as vulnerable; overfishing, including of its aggregation may exacerbate its status. Threats to biodiversity could also arise from the selective targeting of particular species of reef fish for the aquarium trade, but little is known about the impacts of this practice in the region.

<u>Degradation of habitats</u>

Fishing can impact reef habitats through direct damage by fishing gear, boat anchors, vessel groundings, and destructive practices such as the use of explosives and poisons. As seen in Figure 13, reefs throughout the CLME are subjected to very high threat levels from overfishing (Burke and Maidens 2004). Burke et al. (2011) reported that more than 70% of Caribbean reefs are threatened by overfishing. In recent years, commercial fishing on deep water reefs has caused extensive damage to corals and significantly depleted members of the snapper-grouper complex (Koenig et al 2005).

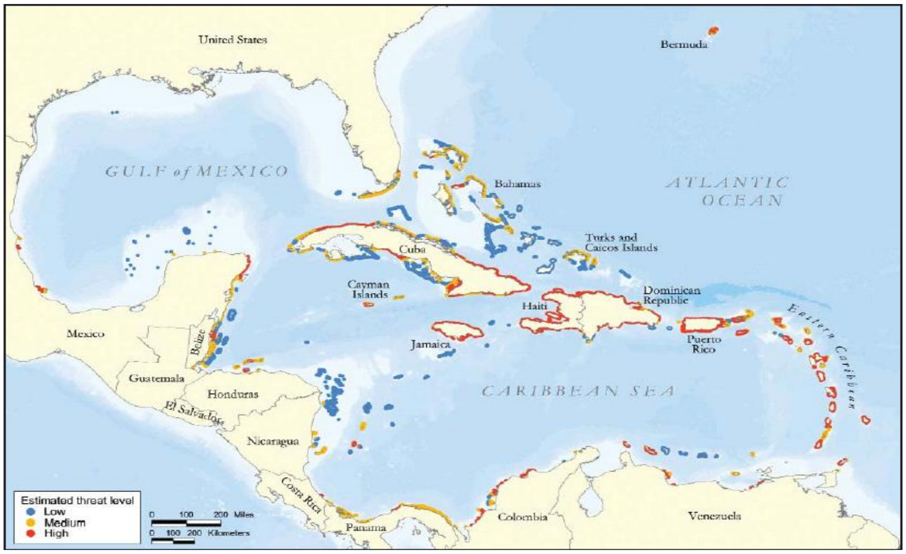


Figure 13 Threats to Caribbean coral reefs from overfishing

Unsustainable fisheries exploitation can also disturb the ecological balance of reef ecosystems, with grave consequences for reef health and productivity. For example, overexploitation of turtles may be a factor in the rise of marine diseases amongst marine organisms generally (Jackson et al 2001). Released from the grazing pressure of green turtles and other over-exploited mega-herbivores, seagrass blades can grow longer and decompose *in situ*, encouraging growth of slime molds that may contribute to seagrass wasting disease.

The impact of overfishing on habitats is clearly demonstrated by the effect of the reduction in the population of herbivorous fish on reef health. Feeding by large herbivores is usually responsible for reducing algal biomass and, in some cases, enhancing coral cover. One of the key factors governing the recovery of coral communities is the maintenance of settlement space and the reduction of algal overgrowth through the actions of herbivores (e.g. Mumby 2006b, Burkepile and Hay 2010). Among the major coral reef fish herbivores are parrotfishes, surgeonfishes, rabbitfishes, and damselfishes. The grazing function of these herbivores is particularly important in areas in which the population of the herbivorous long-spined sea urchin (*Diadema antillarum*) has been decimated during its Caribbean-wide mass mortality in 1983 (Lessios et al. 1984). The scarcity of the urchin persists in most of the Caribbean (Kramer 2003) leaving parrotfishes as the dominant grazer in most areas. Among these, the Caribbean parrotfish (*S. guacamaia*) is usually the most important grazer on Caribbean reefs (Steneck 1994). The population of this species has declined in many areas throughout the CLME, which has serious consequences for the health of the region's coral reefs.

Mumby et al. (2006b) tested the potential importance of marine no-take areas for safeguarding parrotfish and their ability to control blooms of turf and fleshy algae in the Caribbean. They found a greater biomass of parrotfishes and less macroalgae inside a no-take reserve. Results suggested that Caribbean reefs are highly sensitive to fishing of parrotfish. Even intermediate levels of exploitation of parrotfish resulted in a steady decline in coral cover. These findings are consistent with the experimental results presented by Hughes et al (2007), which showed that overfishing of herbivores affects more than just the targeted stocks and can also influence the resilience of coral reefs to climate change. It is obvious that restriction of the level of exploitation of grazing organisms is an important strategy in maintaining coral reef health in the region.

<u>Socio-economic consequences</u>

Unsustainable fishing and decline in fish stocks have important socio-economic consequences throughout the region. Fisheries represent a significant source of employment, income and protein for the CLME countries. This sector continues to act as a 'safety-net' for the economy in many of the countries, i.e., when there is a downturn in other sectors, such as tourism and construction, individuals re-enter or increase their activity in the fisheries sector. As a result, there is a high percentage of part-time fishers in many of the countries. Fish is a major component of the diet and the primary source of protein in the countries. Annual per capita fish consumption reaches up to 20 - 30 kg (live wet weight) in several of the countries, for example, in Barbados, Dominica, and Jamaica

(FAO 2003). Fishing not only provides nutrition and employment but is also a traditional and cultural way of life for many island communities as well as indigenous communities. Declining fisheries may alter the cultural integrity of these communities.

Although in some countries fisheries do not make a significant contribution to GDP compared to other sectors such as tourism, this sector accounts for substantial foreign exchange earnings in some of the countries (FAO Fishery Country Profiles). For instance, in the Bahamas, spiny lobster and queen conch are the most highly demanded commodity for export, with spiny lobster alone generating about 79% - 80% of this sector's revenue. Exports of fish products from the CARICOM region were valued at over US$250 million in the year 2000 (FAO 2000). Unsustainable exploitation could be seriously disruptive for trade and severely reduce foreign exchange earnings, as demonstrated by the CITES trade embargo on queen conch.

Considering the importance of the fisheries sector for food and employment, the decline of fish stocks is likely to have serious socio-economic impacts in these countries. These include loss of employment, reduced food security in communities that depend on fishing, and reduced income. This is particularly significant in countries with a relatively high level of poverty (and considering that small-scale fishers are often among the most economically disadvantaged in society), and countries with high employment in reef fisheries, such as the Turks and Caicos Islands and Dominica, which have significant proportions of reef fishers (5 to 7% of the population) (Burke et al 2011). Erosion of livelihoods and loss of employment in the fisheries sector could lead to increase in criminal activities and migration towards big cities.

In the past decade, the annual value of the region's catches has declined from about US$776 million in 1976 to slightly under US$500 million in 2006 (Figure 14), reflecting the trend in the reduction in landings and change in fish communities to dominance by low value species. As the bulk of the region's fishing fleets still operate inshore, reduced fisheries resources can also lead to conflicts among fishers.

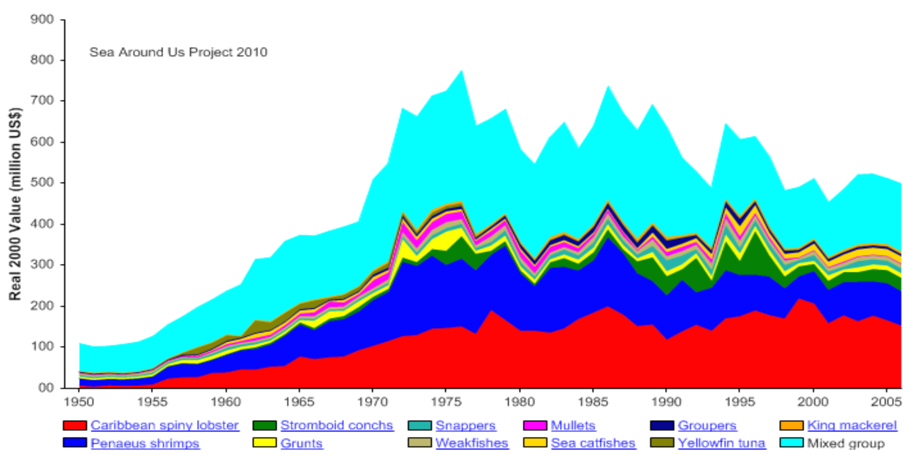


Figure 14. Annual value of the fisheries catches from the CLME

Reduced inshore resources also lead to increasing operational expenses, since fishers have to extend their fishing range offshore. Overfished stocks can also lead to poaching, illegal fishing (e.g. catching of lobsters and conch below the minimum legal sizes), as well as conflicts among between countries for the scarce resources. Reduction in the abundance of reef fish could also have negative consequences for dive tourism, as underwater sites become unattractive, as well as for recreational fishing that is growing in the region.

A positive outcome from unsustainable exploitation is that the ensuing unprofitability could force fishers out of this sector and encourage the development of alternate, more sustainable forms of employment such as ecotourism.

3.2.2. Habitat degradation and community modification

The marine habitats of the CLME are under increasing threat from a range of anthropogenic and natural pressures. Until recently, land-based pollution and overfishing were considered to be the major threats to coral reefs. Today, reefs face additional pressure from thermal stress and emergent diseases that are closely linked to global warming. Over the past several decades, coral reefs have suffered increasingly frequent and widespread coral mortality from diseases, coral bleaching, and algal overgrowth. These factors work individually and synergistically to cause significant large-scale loss of coral cover.

Even deep coral communities are under threat, especially from fishing and oil explorations, such as in Colombia where these unique communities are threatened by the development of new fishing technologies and the expansion of oil and gas exploration (Santodomingo al. 2004).

Burke and Maidens (2004) integrated four major threats to Caribbean reefs (coastal development, marine-based threats, overfishing, land-based sediment and pollution) into the Reefs at Risk Threat Index, which showed that nearly two-thirds of the region's coral reefs are threatened by human activities, with overfishing being the major threat. An update of this assessment[11] (based on overfishing and destructive fishing, coastal development, watershed-based pollution and marine-based pollution and damage) has revealed an increase in the proportion of Caribbean reefs threatened by human activities to more than 75%, with more than 30% in the high and very high threat categories (Burke et al. 2011). Climate-related threats are projected to push the proportion of reefs at risk in the Caribbean to 90% in the year 2030, and up to 100%, with about 85 % at high, very high, or critical levels, by 2050. The reefs considered to be under low threat are almost entirely in areas remote from large land areas, such as the Bahamas and the oceanic reefs of Honduras and Nicaragua.

The Insular Caribbean is particularly threatened. From Jamaica through to the Lesser Antilles, more than 90% of all reefs are threatened, with nearly 70% classified as at high or very high threat (Figure 15; Burke et al 2011). As shown in Table 10, the highest threat index is found in St. Lucia, followed by Haiti, Grenada, Dominica and Jamaica. Most of

[11] Reefs at Risk Revisited.

these areas in the Insular Caribbean are affected by multiple threats, with coastal development and watershed-based pollution the most severe.

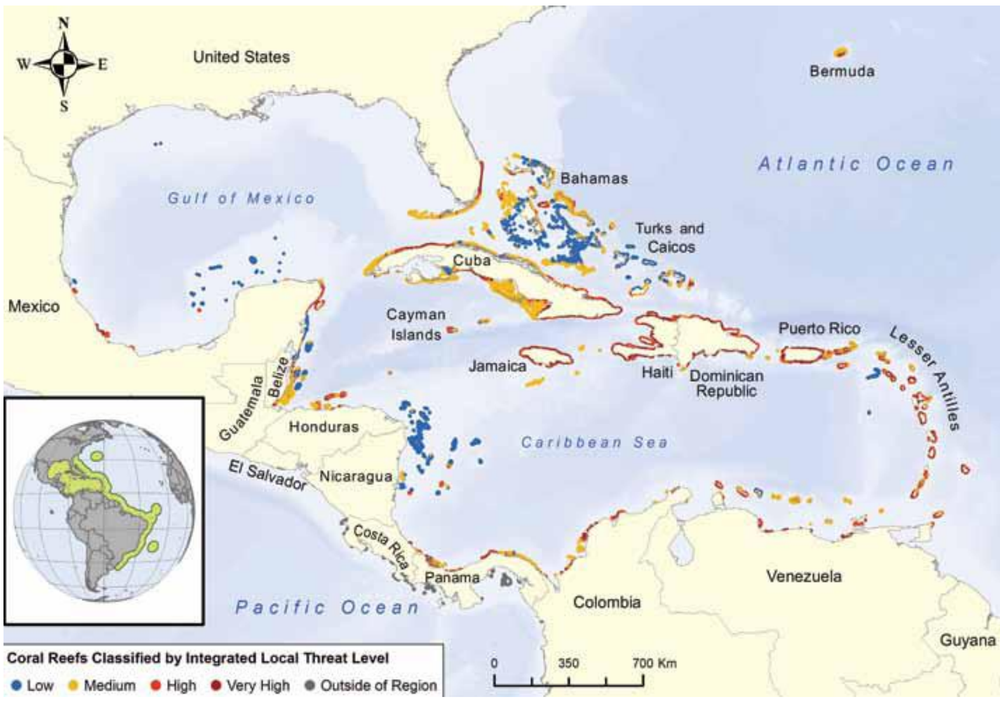


Figure 15. The Reefs at Risk in the Caribbean

Table 10. Percentage of coral reefs at medium and high risk from four individual threats in Caribbean Islands; Reefs at Risk Threat Index

(L: low; M: medium; H: high; VH: very high) (Burke and Maidens 2004)

Country/territory	Coastal development	Sedimentation & pollution from inland sources	Marine-based pollution	Overfishing	Reefs at risk Threat Index (%)			
					L	M	H	VH
Antigua & Barbuda	71	29	29	100	0	39	50	11
Aruba	100	0	74	100	0	0	85	15
Bahamas	5	0	1	22	75	24	2	0
Barbados	100	60	15	100	0	0	86	14
Cuba	21	28	8	68	32	32	33	3
Dominica	96	100	14	100	0	0	63	37
Dominican Republic	59	45	10	79	18	8	63	10
Grenada	85	57	23	100	0	20	41	40
Haiti	92	99	7	100	0	0	45	55
Jamaica	55	61	31	69	32	2	34	32
Netherland Antilles	43	0	45	36	37	15	39	9
St. Kitts & Nevis	95	100	26	100	0	0	77	23
St. Lucia	99	100	40	100	0	0	39	61
St. Vincent & the Grenadines	64	16	29	100	0	38	48	14
Trinidad & Tobago	99	87	1	100	0	0	99	1
Virgin Islands (US)	58	34	44	61	0	9	73	18

More recently, an ecoregional assessment of the MAR conducted under the Nature Conservancy's Mesoamerican Reef Programme included an analysis of threats to the biodiversity of this system (Arrivillaga and Windevoxhel 2008). Results of this analysis are summarized in Table 11. All five habitat types shown are conservation targets, and are subjected to a variety of threats. Coral reefs in particular are under very high threat from global climate change and unsuitable aquatic tourism practices. The overall threat is very high for coral reefs and high for the other four habitats.

Table 11. Analysis of threats to the conservation targets in the MesoAmerican Reef

Threats	Coral Reefs	Seagrass beds	Beaches and coastal dunes	Mangrove forests	Estuaries and coastal lagoons	SPAGs	Whale shark	Overall value of threat
Global climate change (temperature and sea level rise and elevation f CO_2)	Very high	Medium	Low	High	Medium	-	-	High
Unsuitable aquatic tourism activities	Very high	Low	-	-	Medium	Low	High	High
Wastewater discharge	High	High	-	Low	High	Medium	Low	High
Tourism infrastructure development	Medium	High	High	High	-	-	-	High
Sedimentation	High	High	-	Low	High	-	-	High
Coastal urban development	-	-	High	High	High	-	-	High
Overfishing and unsuitable fishing practices (spear fishing, trawling, Scuba)	High	Medium	-	-	Medium	High	-	High
Agro-chemical and pesticide use	High	High	Low	Low	Medium	-	-	High
Navigation (anchor damage, oil spills, boat scars)	High	Low	Medium	Low	Medium	-	Medium	Medium
Highway and transportation infrastructure development	High	Medium	Medium	Medium	Low	-	-	Medium
Accumulation of solid wastes	-	-	High	-	-	-	Medium	Medium
Invasive species	High	-	Low	-	-	-	-	Medium
Extensive animal husbandry	-	-	-	High	-	-	-	Medium
Shrimp aquaculture	-	Medium	Medium	Medium	Medium	-	-	Medium
Natural disasters	-	Medium	Medium	-	-	-	-	Medium
Mining	-	-	Low	-	Medium	-	-	Low
Overall status of threats to conservation targets	Very High	High	High	High	High	Medium	Medium	Very High

The incidence of an unprecedented array of new coral reef diseases has been reported with increasing frequency in the Caribbean (Woodley et al. 2000, Burke and Maidens 2004). In fact, most reported observations of diseases affecting coral reefs worldwide have been in the Caribbean. Reefs throughout the Caribbean Sea have been affected by diseases, particularly in the Insular Caribbean, as shown in Figure 16 (Burke and Maidens 2004). Prominent among these reports have been the Caribbean-wide die-off of the long-spined black sea urchin (*Diadema antillarum*) from disease; widespread losses of major reef-building corals (staghorn and elkhorn) due to white band disease; the widespread occurrence of Aspergillosis, a fungal disease of some species of sea fans; and numerous outbreaks of white plague.

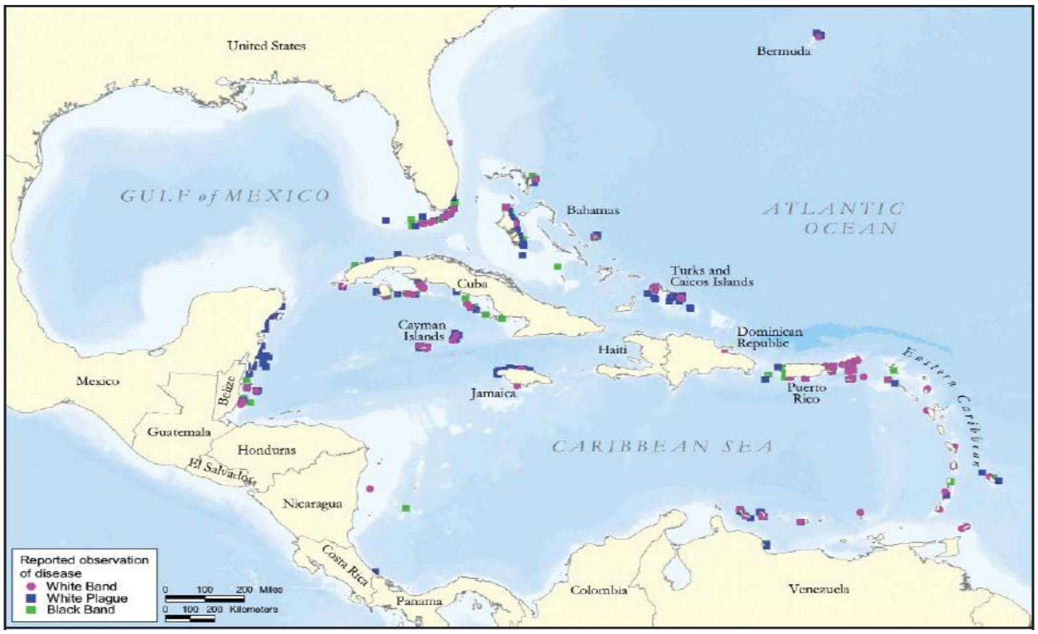


Figure 16. Coral disease observations in the Caribbean

In 1983, an unidentified disease spread throughout the Caribbean and killed 99% of the long-spined sea urchin (Lessios et al 1984). This species is an efficient algal grazer that helps to keep corals from being overgrown by algae. Although densities of *Diadema* have increased in a few areas and in shallow water, their density remains low throughout much of the Caribbean, and particularly so on mid-depth fore reefs. Kramer (2003) found that urchins were absent in half of all sites sampled and the mean density was very low where they did occur. In Jamaica the lack of coral recovery at many sites impacted by hurricanes, coral disease, and long-term overfishing could be attributed to loss of sea urchins (Aronson and Precht 2000).

Coral bleaching is set to become one of the most serious and widespread threats to the region's reefs. Corals bleach when the coral animal host is stressed and expels the symbiotic zooxanthellae (algae) that provide much of the energy for coral growth, and coral reef growth. Although several different stresses cause bleaching, by far the most significant cause of coral bleaching in the past 25 years has been SSTs that exceed the normal summer maxima by 1 or 2°C for at least 4 weeks.

The most extreme coral bleaching and mortality event to hit the Wider Caribbean (including Atlantic) coral reefs in 2005 has been documented by Wilkinson and Souter (2008) and clearly illustrates the severe impact that climate change could have on the region's reefs. The year 2005 was the hottest year in the Northern Hemisphere on average since the advent of reliable records in 1880. Large areas of particularly warm surface waters developed in the Caribbean and Tropical Atlantic during 2005 and were clearly visible in satellite images as hotspots (Figure 17). The warm water caused massive, large-scale coral bleaching throughout the region, with up to 100% of corals affected in some sites. The greatest damage occurred in the Lesser and Greater Antilles where corals were immersed in abnormally warm waters for 4 to 6 months. The greatest coral mortality occurred in the US Virgin Islands, which suffered an average decline of 51.5% due to bleaching and subsequent disease; the worst seen in more than 40 years of observations. There has been little recovery in the Caribbean since this event.

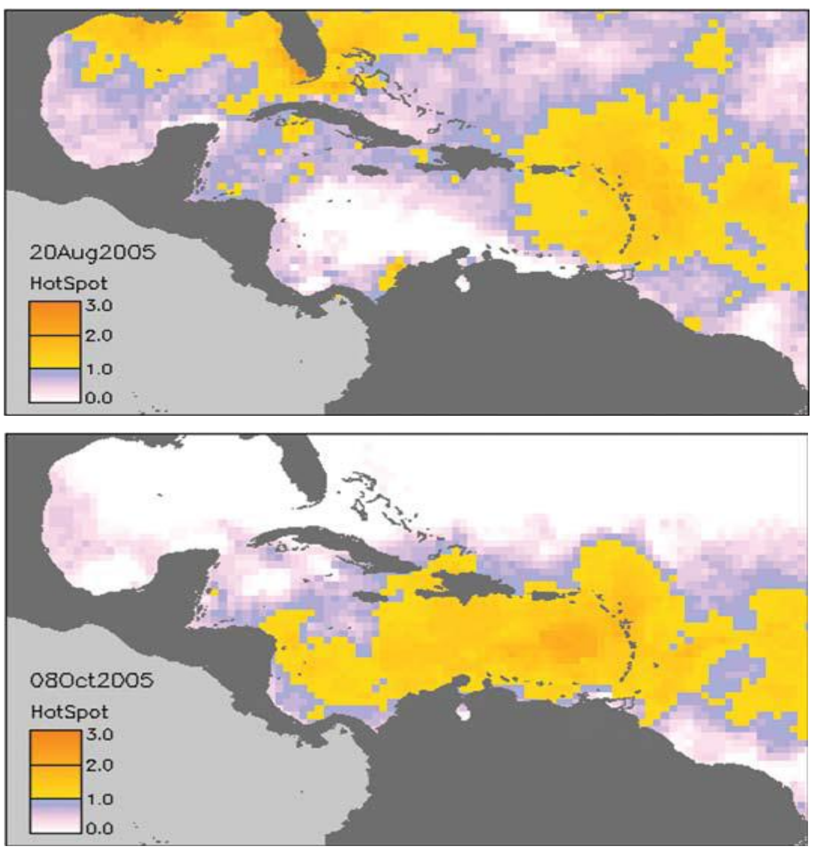


Figure 17. Sea Surface Temperature hotspots in the Caribbean Sea in 2005

Top: NOAA satellite image from mid-August 2005 showing a dramatic expansion of two hotspots with temperatures 2ºC to 3ºC in excess of the summer maximum covering large parts of the Northern Caribbean. Bottom: The peak of hotspot activity occurred in early October with a massive area of warm water covering virtually all the central and eastern Caribbean (Wilkinson and Souter 2008).

Increased prevalence of disease following bleaching was also reported from many islands of the Lesser Antilles, particularly the French West Indies. Further, hurricanes in 2005 exacerbated the damage to coral reefs caused by bleaching and disease, although the effects were not all bad. Some hurricanes reduced thermal stress by mixing deeper cooler waters into surface waters. None of these hurricanes, however, passed through the Lesser Antilles to cool the waters, where the largest hotspot persisted.

The year 2010, however, may be the worst year ever for coral death in this region. Abnormally warm water since June appears to have dealt a blow to shallow and deep-sea corals that is likely to top the devastation of 2005. The NOAA Coral Reef Watch (CRW) satellite coral bleaching monitoring shows SSTs continue to remain above average throughout the Wider Caribbean region. The CRW Coral Bleaching Thermal Stress Outlook continues to indicate a high potential for thermal stress capable of causing significant coral bleaching in the southern Caribbean in 2010. The region at greatest risk extends east from Nicaragua past the island of Hispaniola to Puerto Rico and the Lesser Antilles, and south along the Caribbean coasts of Panama and South America (Figure 18). Temperature maps indicate that the water has remained warm for longer than in the 2005 episode and the abnormal warmth spreads over a much broader area. In 2010, the bleaching and high temperatures devastated reefs in the Dutch Antilles and affected coral along the western and southern areas of the Caribbean Sea, including reefs off Panama and Curaçao. The extent of the devastation across the rest of the Caribbean is still to be seen.

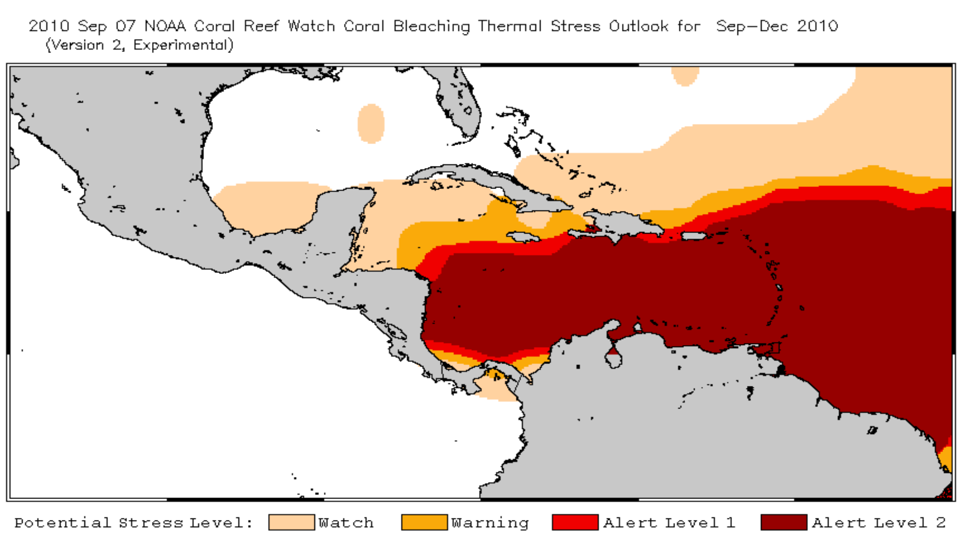


Figure 18. Caribbean Coral Bleaching Thermal Stress Outlook for September-December 2010, issued on September 7, 2010

(http://coralreefwatch.noaa.gov/satellite/bleachingoutlook/outlook_messages/bleachingoutlook_20100907_for_2010sepdec.html#caribbean)

In addition to bleaching, corals and other organisms with calcareous structures are subjected to increasing stress from ocean acidification. A recent study confirmed significant ocean acidification across much of the Caribbean and Gulf of Mexico, and reported strong natural variations in ocean chemistry in some parts of the Caribbean that could affect the way reefs respond to future ocean acidification (NOAA 2008). While ocean chemistry across the Caribbean region is currently deemed adequate to support coral reefs, it is rapidly changing as atmospheric carbon dioxide levels rise. Carbon dioxide is neutralized in the ocean by the dissolution of marine carbonates (including aragonite), which are used by corals and other shelled marine organisms that rely on aragonite for their structure. In the CLME region, increasing atmospheric carbon dioxide concentrations resulted in less aragonite and other minerals saturation. Compared to pre-industrial levels (around 5), aragonite and other minerals in the ocean have decreased (to around 3.5 - 4) resulting in increased acidification (UNEP- CAR/RCU 2011).

The most difficult aspect of detecting climate induced changes in exploited stocks is distinguishing them from changes resulting from exploitation and environmental degradation. Although no studies have been conducted to show direct links between rising SST and fish stocks in the CLME, modeling of the impacts of rising SST on global fish biomass indicates that tropical regions will suffer the greatest negative impacts (Cheung et al 2009a).

Climate change can affect reef fish through impacts on the distribution patterns of reef fish, on early life history stages, and indirectly through impacts on coral reef and other coastal habitats. Reducing local threats, however, will help corals to be more resilient in the face of rising SST. In 1998, a mass coral bleaching event caused significant coral mortality on the Mesoamerican Reef. However, some coral species in areas where the reef and surrounding waters were relatively free of sediment were able to recover within two to three years, while corals living with excessive local impacts were not able to fully recover even eight years after the event[12].

In addition to the impacts of global warming on coral reefs, an increase in the frequency and magnitude of storms and hurricanes as well as sea level rise are serious concerns for the region. These would increase the risk of flooding, including of mangrove habitats, and accelerate existing rates of beach erosion. Changes in rainfall patterns could also alter the flow of freshwater to coastal habitats that are dependent on inputs of freshwater and nutrients from terrestrial areas.

Under a current project "The Future of Reefs in a Changing Environment (FORCE): An ecosystem approach to managing Caribbean coral reefs in the face of climate change", a multidisciplinary team of researchers from Europe and the Caribbean are partnering to enhance the scientific basis for managing Caribbean coral reefs in an era of rapid climate change and unprecedented human pressure on coastal resources (http://www.force-project.eu/). The overall aim is to provide coral reef managers with a toolbox of sustainable management practices that minimize the loss of coral reef health and biodiversity. An

[12] In Burke et al (2011) based on story from A. Reisewitz and J. Carilli of the Scripps Institution of Oceanography at the University of California, San Diego

ecosystem approach is being taken that explicitly links the health of the ecosystem with the livelihoods of dependent communities, and identifies the governance structures needed to implement sustainable development.

Plant and animal communities could be significantly modified by the introduction of exotic species that become invasive. The high level of international shipping traffic in the Caribbean Sea poses a potential danger to the ecosystem from exotic species. Shipping accounts for the introduction of significant quantities of ballast water into the Caribbean Sea. Of the six million tonnes of ballast water that was poured into the Caribbean Sea in 2005, 84% came from international shipping (UNEP CAR-SPAW-RAC 2010). Two well-known examples of invasive species that were introduced through shipping are the red lionfish (*Pterois volitans*), native to the Pacific Ocean, and the Indo-Pacific green mussel (*Perna viridis*). Recreational divers reported seeing lionfish in 2004, and in 2007 the first published record of lionfish suggested that their range was expanding rapidly throughout Little Bahamas, Grand Bahama Banks and the Caribbean. The green mussel has been accidentally introduced in boat hull and ballast water to the Caribbean, where it is now well-established. This exotic species was first introduced in waters around Trinidad in 1990 (Agard et al. 1992) and later along the coast of Venezuela in 1993 (Rylander et al. 1996). In 1999, it was observed in Tampa Bay, Florida, where they were discovered clogging cooling water intake tunnels at several power plants.

The International Convention for the Control and Management of Ship Ballast Water and Sediments addresses the issue of ballast water and the problem of invasive species in the region. In 2000, the International Maritime Organization (IMO) launched a pilot project (GloBallast), which aimed to reduce the transport of harmful organisms in ballast water. Following this project, the IMO has implemented another project "Building Partnerships to Assist Developing Countries to Reduce the Transfer of Harmful Aquatic Organisms in Ships' Ballast Water" or the GloBallast Partnerships project. This project mainly aims to help developing countries reduce the risk of invasion of aquatic organisms in ballast water. Four Caribbean countries are main project partners in the Caribbean component: the Bahamas, Jamaica, Trinidad and Tobago, and Venezuela. A number of other Caribbean countries are partners in this project.

The Bahamas, the Dominican Republic, Jamaica, St. Lucia, and Trinidad and Tobago are also involved in the GEF project "Mitigating the threats of Invasive Alien Species in the Insular Caribbean", which is helping the countries to develop strategies and actions on the regional and national levels to mitigate the impact of invasive alien species in the Insular Caribbean. This project is being implemented by CABI, and is closely linked to the SPAW Protocol and its work programme.

The major environmental impacts of habitat degradation and community modification include:

i. Loss of ecosystem structure and function;
ii. Reduction/loss of biodiversity;
iii. Reduction in fisheries productivity and other ecosystem services.

Loss of ecosystem structure and function

The health and productivity of ecosystems depends on them maintaining their structure and function. Degradation of these habitats not only compromises their ecosystem structure and functioning, which reduces their resistance and resilience to external perturbations, but also leads to reduction or loss of the ecosystem services they provide to humans.

Recent studies have revealed a trend of serious and continuing long-term decline in the health of the region's coral reefs (Wilkinson 2002, Gardner et al 2003, Kramer 2003). In some areas, up to 80% of shallow-water reefs have been destroyed, as illustrated in Figure 19 (Gardner et al 2003). Overall, about 30% of Caribbean reefs are now considered to be either destroyed or at extreme risk from anthropogenic pressures (Wilkinson 2000). In the absence of greater efforts to manage and protect these reefs, another 20% or more are expected to be lost over the next 10 - 30 years (Wilkinson 2000).

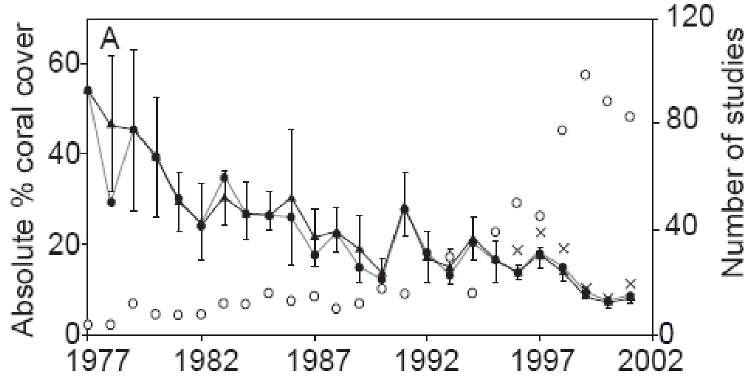


Figure 19. Absolute per cent coral cover from 1977 to 2001 across the Caribbean Basin

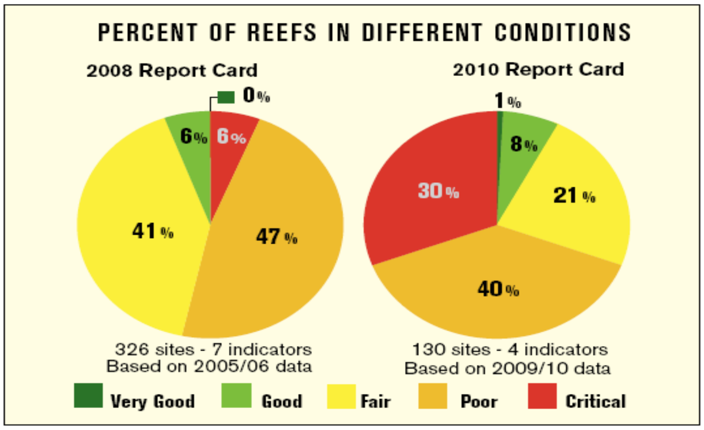
The trend line represents the decline in percentage live coral cover based on weighted means of several studies, the exact number of which are shown by open circles. The error bars indicate 95% confidence intervals (Gardener et al 2003).

These trends are also reflected in the transboundary MesoAmerican Reef, where 70% of the reefs surveyed in 2009/2010 were in a poor and critical condition, compared to 53% in 2005/2006 (Box 6).

Box 6. **Mesoamerican Reef report card**

Mesoamerican Reef report card

The recently released 2010 Reef Report Card for the Mesoamerican Reef (MAR), which runs from Mexico's Yucatán Peninsula south through Belize, Guatemala and Honduras compares change in the health of the MAR in 2006 and 2009 (Healthy Reefs for Healthy People 2010). Overall, the reef experienced a 20% decline in health from 2006 to 2009, with a sharp drop in reefs considered to be in "fair" condition, from 41% of the total in 2006 to just 21% in 2009. The overall condition of the 130 reefs surveyed (and evaluated with four indicators) found 31% of reefs in 'critical' condition, 38% in 'poor', 24% in 'fair', 6% 'good' and 1% 'very good' condition. The four major factors that have contributed to deterioration of reef health are coastal development and marine dredging; inland land-clearing and agriculture; overfishing; and climate change. In addition, two new threats have emerged: the growing prospects for offshore oil drilling in the region, and the sudden population boom of the red lionfish.



Reef condition of the MAR in 2006 and 2009 (Healthy Reefs for Healthy People 2010. http://healthyreefs.org/eco-health-report-card/report-card.html)

The region's reefs are experiencing an unprecedented array of new coral reef diseases with increasing frequency in the Caribbean (Burke and Maidens 2004) and coral bleaching from rising SSTs (Spalding 2004). Coral diseases have contributed to the extensive loss of two important reef-building corals—staghorn (*Acropora cervicornis*) and elkhorn (*A. palmata*) (Precht 2002).

Since the early 1980s repeated coral bleaching incidents have caused widespread damage to reef-building corals and contributed to overall decline in reef condition throughout the Caribbean (Spalding 2004). In some areas throughout the Caribbean, up to 100% of corals have been affected by bleaching.

With the loss of the sea urchins, in just two years fleshy algae came to dominate coral reefs in some localities, notably in Jamaica that has some of the most intensively fished reefs in the Caribbean (Pandolfi et al. 2003). As previously mentioned, overgrowth of corals by algae is exacerbated by declines in biomass of grazing fish species such as parrot fish. Monitoring of live coral cover by the Caribbean Coastal Marine Productivity Programme (CARICOMP) between 1993 and 2001 found declines in live coral on nearly two-thirds of the sites investigated.

As previously discussed, overfishing of grazers such as parrotfish have been shown to slow the recovery of corals that have been damaged by bleaching and other pressures because of algal overgrowth with reduction in grazing pressure on algae. Among the measures to be included in the toolbox being developed by the FORCE project will be fisheries policies that balance herbivore extraction against the needs of the ecosystem, the incorporation of coral bleaching into marine reserve design, and creation of livelihood enhancement and diversification strategies to reduce fisheries capacity. Steneck et al (2009) reviewed information on how connectivity links networks of no-take reserves (NTRs) and the important role that habitat receptivity plays in linking larval dispersal to population persistence. Reef connectivity could be compromised by the increased fragmentation of reef habitat due to the effects of coral bleaching and ocean acidification (Munday et al 2009). Changes to the spatial and temporal scales of connectivity have implications for the management of coral reef ecosystems, especially the design and placement of MPAs. The size and spacing of protected areas may need to be strategically adjusted if reserve networks are to retain their effectiveness in the future.

Alvarez-Filip et al (2009) provided the first Caribbean-wide analysis of changes in reef architectural complexity, using nearly 500 surveys across 200 reefs, between 1969 and 2008. Results showed that the architectural complexity of Caribbean reefs has declined nonlinearly with the near disappearance of the most complex reefs over the last 40 years (Figures 20 and 21). Flattening of Caribbean reefs was apparent by the early 1980s. Rates of loss are similar on shallow (<6 m), mid-water (6-20 m) and deep (>20 m) reefs and are consistent across all five subregions studied. The temporal pattern of declining architecture coincides with key events in recent Caribbean ecological history: the loss of structurally complex *Acropora* corals, the mass mortality of the sea urchin, and the 1998 ENSO-induced worldwide coral bleaching event. The consistently low estimates of current architectural complexity suggest regional-scale degradation and homogenization of reef structure.

This widespread loss of rugosity is likely to have serious consequences for reef biodiversity, ecosystem functioning and associated ecosystem services. Reductions in coral cover have strongly reduced the abundance and diversity of fishes that have a direct obligate dependence on live coral for settlement habitat or food (Munday 2004). In some cases, the reduction in living coral has precipitated a shift in fish communities from trophic and habitat specialists to generalists. Declines in the structural complexity of coral habitats have also been found to reduce the diversity of invertebrate taxa (Idjadi and Edmunds 2006) and the density of commercially important invertebrates such as the spotted spiny lobster, *Panulirus guttatus* (Wynne and Cote 2007).

Today the phenomenon of habitat loss is occurring at such large scales (thousands of kilometres) that it might encompass most subpopulations of a meta-population and therefore reduce population stability. At best, this will exacerbate the ongoing concerns over overexploitation of fisheries and at worst, threaten the very persistence of some species (Mumby and Steneck 2008).

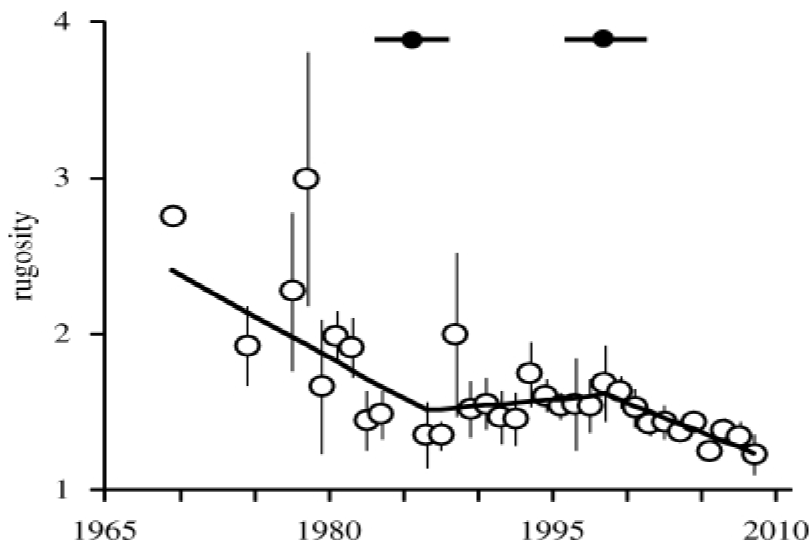


Figure 20. Changes in reef rugosity on reefs across the Caribbean from 1969 to 2008

Black line represents the best fitting model—a segmented regression weighted by the number of sites contributing to each annual rugosity estimate (mean ± 95% confidence intervals). Black dots at the top of the figure indicate the significant breakpoint in 1985 and 1998 (±1 s.e.) for the segmented regression. Model slopes: 1969–1984, −0.054; 1985–1997, 0.008; 1998–2008, −0.038. (Alvarez-Filip et al 2009)

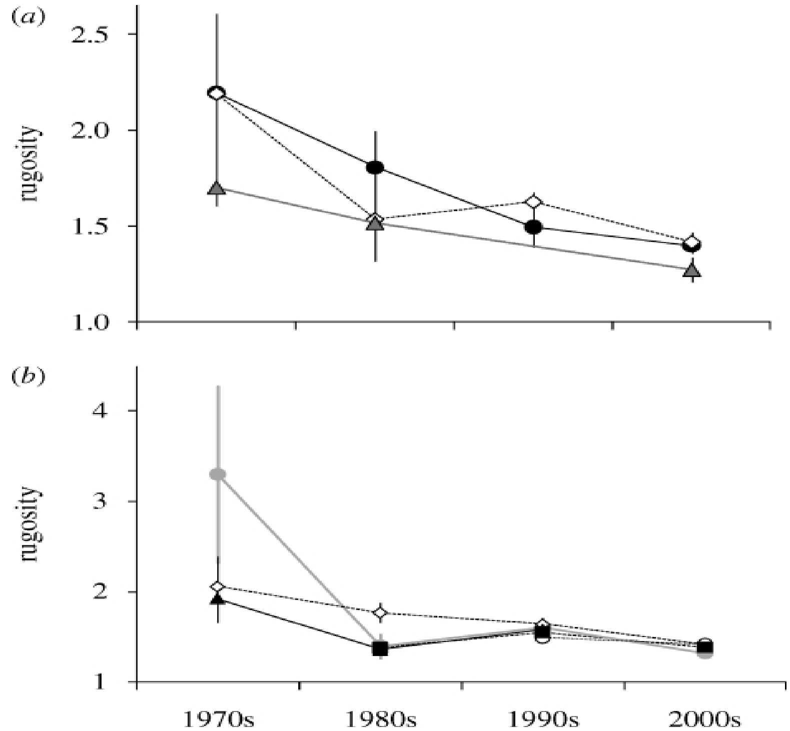


Figure 21. Change in Caribbean reef rugosity in four different decades (*a*) at three depth intervals

(filled circle, 0–6 m; open diamond, 6–20 m; filled triangle, 20 m) and (*b*) in five subregions (filled square, southwest North Atlantic; grey circle, greater Antilles; open diamond, lesser Antilles; filled triangle, South America; open circle, Central America) (mean index value ± 95% confidence intervals) (Alvarez-Filip et al 2009).

Mangroves and seagrass beds are also fast disappearing largely because of cutting and filling for coastal development (associated with the industrial, residential, urban, tourism, and recreational sectors), conversion for salt production, aquaculture, and agriculture purposes as well as for mosquito control. These habitats are also impacted by pollution from runoff of fertilizers and pesticides, and improper disposal of wastes. The cutting of mangrove trees for use in construction and production of charcoal is a common practice of Caribbean coastal communities. Mangroves in the CLME region have also been destroyed by hurricanes. Among all these causes, however, the main regional cause of mangrove loss over the last 25 years has been reclamation of land for urban and tourism development (FAO 2007).

Table 12 shows the change in mangrove area for CLME countries (FAO 2007). This covers both the Caribbean and Pacific coasts for the relevant countries in Central and South America. Between 1980 and 2005, most of the countries in the Caribbean showed decreasing mangrove cover, with the highest loss between 2000 and 2005 recorded in Barbados followed by US Virgin Islands and Antigua and Barbuda. During this period, a net increase in mangrove area was experienced only by Cuba and Puerto Rico. This could be attributed to a major plantation programme and mangrove protection legislation and enforcement in Cuba; and increased legal protection, natural colonization of new areas, and the reversion of agricultural land to its original mangrove state in Puerto Rico (FAO 2007). Despite the continued loss of mangrove area in 2000 - 2005, the annual rate of mangrove area loss in this period (compared to previous 5-year period) decreased in 24 countries as a result of increased awareness in the region.

Conversion of mangroves to other uses (as opposed to simply cutting of mangrove trees) has a greater damaging impact on the ecosystem and connectivity and makes mangrove restoration more difficult if not impossible (N. Windevoxhel, pers. comm.). Destruction of mangrove forests and seagrass beds results in loss of their ecosystem services such as protective and nursery functions, making the coast more vulnerable to storm surges, erosion, and land based pollution, and destroying the nursery habitat of many commercially important species.

Extraction of sand for construction from beaches and dunes has led to severe damage of these areas in some countries. For example, in Antigua and Barbuda, demand from the construction industry and lack of suitable alternative sources of building sand has resulted in extensive mining of sand from beaches around the island, despite legal restrictions designed to regulate sand removal. Some beaches have been so badly mined that they have been converted to rocky shores. One of the impacts of the loss of sandy beaches is reduction in nesting sites for sea turtles.

Table 12. Status and trends in mangrove area by country and in North and Central America between 1980–2005

Country/ area	Most recent reliable estimate		1980	1990	Annual change 1980–1990		2000	Annual change 1990–2000		2005	Annual change 2000–2005	
	ha	Ref. year	ha	ha	ha	%	ha	ha	%	ha	ha	%
Anguilla	90	1991	90	90	0	0	90	0	0	90	0	0
Antigua and Barbuda	1 175	1991	1 570	1 200	–37	–2.6	850	–35	–3.4	700	–30	–3.8
Aruba	420	1986	420	420	0	0	420	0	0	420	0	0
Bahamas	141 957	1991	180 000	145 000	–3 500	–2.1	140 000	–500	–0.3	140 000	0	0
Barbados	4	2004	30	16	–1	–6.1	7	–1	–7.9	4	–1	–10.6
Belize	78 511	1990	78 500	78 500	0	0	76 500	–200	–0.3	76 000	–100	–0.1
Bermuda	16	1992	17	16	n.s.	–0.6	15	n.s.	–0.6	15	0	0
British Virgin Islands	587	2001	660	630	–3	–0.5	590	–4	–0.6	570	–4	–0.7
Cayman Islands	7 830	1998	8 500	8 000	–50	–0.6	7 700	–30	–0.4	7 600	–20	–0.3
Costa Rica	41 840	2000	63 400	53 400	–1 000	–1.7	41 800	–1 160	–2.4	41 000	–160	–0.4
Cuba	545 805	2003	537 400	541 400	400	0.1	545 500	410	0.1	547 500	400	0.1
Dominica	10	1991	12	10	n.s.	–1.8	10	0	0	9	n.s.	–2.1
Dominican Republic	21 215	1998	34 400	25 800	–860	–2.8	19 400	–640	–2.8	16 800	–520	–2.8
El Salvador	28 000	2004	46 700	35 300	–1 140	–2.8	28 500	–680	–2.1	28 000	–100	–0.3
Grenada	255	1992	295	260	–4	–1.2	230	–3	–1.2	215	–3	–1.3
Guadeloupe	2 950	1997	3 000	2 990	–1	n.s.	2 960	–3	–0.1	2 950	–2	–0.1
Guatemala	17 727	1999	18 600	17 400	–120	–0.7	17 500	10	0.1	17 500	0	0
Haiti	15 000	1988	17 800	15 000	–280	–1.7	14 300	–70	–0.5	13 700	–120	–0.8
Honduras	78 668	2000	152 500	118 400	–3 410	–2.5	78 700	–3 970	–4	67 200	–2 300	–3.1
Jamaica	9 731	1997	12 000	10 700	–130	–1.1	9 700	–100	–1	9 600	–20	–0.2
Martinique	1 840	1998	1 900	1 900	0	0	1 800	–10	–0.5	1 800	0	0
Mexico	882 032	2002	1 124 000	985 600	–13 840	–1.3	885 000	–10 060	–1.1	820 000	–13 000	–1.5
Montserrat	5	1991	5	5	0	0	5	0	0	5	0	0
Netherlands Antilles	1 138	1980	1 140	1 100	–4	–0.4	1 000	–10	–0.9	1 000	0	0
Nicaragua	69 050	1998	103 400	79 300	–2 410	–2.6	65 000	–1 430	–2	65 000	0	0
Panama	174 435	2000	250 000	190 000	–6 000	–2.7	174 400	–1 560	–0.8	170 000	–880	–0.5
Puerto Rico	8 870	2000	7 650	8 300	65	0.8	8 900	60	0.7	9 000	20	0.2
Saint Kitts and Nevis	79	1991	85	80	–1	–0.6	75	–1	–0.6	70	–1	–1.4
Saint Lucia	200	2002	200	200	0	0	200	0	0	200	0	0
Saint Vincent and the Grenadines	51	1991	55	51	n.s.	–0.7	50	n.s.	–0.2	50	0	0
Trinidad and Tobago	7 150	1991	7 500	7 170	–33	–0.4	7 000	–17	–0.2	7 000	0	0
Turks and Caicos Islands	23 600	1988	23 600	23 600	0	0	23 600	0	0	23 600	0	0
United States	197 648	2001	275 000	240 000	–3 500	–1.3	200 000	–4 000	–1.8	195 000	–1 000	–0.5
US Virgin Islands	216	1999	350	320	–3	–0.9	200	–12	–4.6	150	–10	–5.6
North and Central America	2 358 105	2000	2 950 779	2 592 158	–35 862	–1.29	2 352 002	–24 015	–0.97	2 262 748	–17 851	–0.77

Note: n.s. = not significant.

Reduction/loss of biodiversity

Coastal habitats are critical for marine biodiversity, serving as essential habitats for many fish, molluscs, crustaceans, sea turtles as well as some marine mammals. Among these are species that are considered endangered. Dramatic changes in the community structure of Caribbean coral reefs have taken place in recent years. For example, prior to the 1980s, scleractinian (stony) corals dominated these reefs and the abundance of macroalgae was low. Over the past two decades, a combination of anthropogenic and natural stressors has caused a reduction in the abundance of hard corals and an increase in macroalgae cover. Staghorn and elkhorn corals and sea fan are listed as Critically Endangered on the IUCN Red List, because of population reductions exceeding 80%, in particular due to the effects of disease as well as climate change and human-related factors.

The recent region-wide declines in Caribbean coral reef fish density across sub-regions (Figure 22) and across a range of species throughout the Caribbean suggests that fishes in this region are now declining in response to habitat-related changes (Paddack et al 2009). For example, it has been found that human pressures in coastal zones, potentially dominated by exploitation, have led to the broad-scale absence of sharks on reefs in the greater Caribbean (Ward-Paige et al 2010). Using an extensive database of fish surveys conducted by trained recreational divers it was shown that contemporary sharks, other than nurse sharks, are largely absent on reefs in the greater Caribbean (Ward-Paige et al 2010). Comparison with data on human population density suggests that such disappearance may have been related to anthropogenic pressures. This study revealed that sharks on reefs in the greater-Caribbean occurred mostly in areas with very low human population density or in a few places where strong fishing regulations or conservation measures are in place. Beyond direct exploitation, the presence of human settlements can lead to habitat degradation and destruction, which can reduce the area that is suitable for sharks.

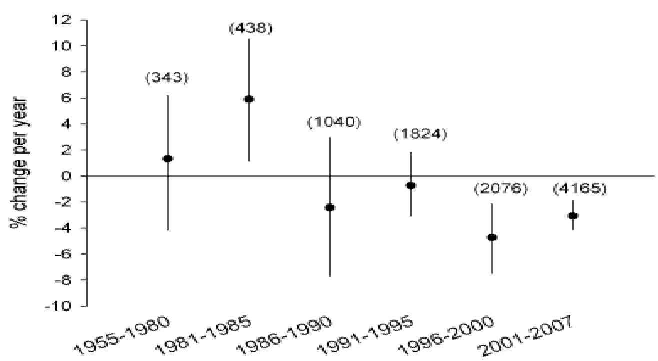


Figure 22. Annual percent change in fish density/m^2/per 5-year period.

Bars are 95% confidence intervals. Sample sizes are given in parentheses and represent the number of individual fish density estimates included in the analysis for each group.

Habitat degradation and loss, along with overfishing, is also responsible for the massive decline in Caribbean populations of sea turtles and marine mammals such as the manatee. Populations of endangered Caribbean green and hawksbill sea turtles have declined significantly since the 17th Century, with the number of green turtles throughout the Caribbean falling from 91 million to 300,000 and the population of hawksbill turtles plunging from 11 million to less than 30,000 during this same time period (McClenachan et al 2006). The change represents a 99.7% drop in historic Caribbean sea turtle populations for the two species. This could be partly attributed to the loss of 20% of historic nesting sites due to land development and turtle exploitation, and another 50% of the remaining sites having been reduced to dangerously low populations. Three problems that are particularly prevalent in the Insular Caribbean are mining of beach sand for construction, loss of nesting habitat to beach-front development and construction, and the effects of beach-front lighting. The latter deters females from coming to shore to nest and disorient hatchlings in their critical journey to the sea.

Similarly throughout the region, the loss of foraging habitat presents a significant management challenge. Losses accrue through the degradation and destruction of seagrass and live coral reef and more general degradation (e.g. from pollution, anchoring, over-fishing and marine recreational activities) of shallow coastal ecosystems, including mangrove and estuary habitats, that offer refugia, harbour prey species, and provide other important services. Marine turtle nesting and foraging habitats have been set aside in legally protected areas in a number of countries, but there is a need for much broader consideration of marine turtle management needs as part of environmental impact assessment of coastal development projects.

Globally, the highest proportion of threatened mangrove species is found along the Atlantic and Pacific coasts of Central America (Polidoro et al 2010) (Figure 23). Extensive clearing of mangroves for settlement, agriculture and shrimp ponds are the major causes of mangrove decline in Latin America. Alteration of freshwater inputs to coastal areas can also cause degradation of these habitats. For example, water diversion in the Magdalena delta/lagoon complex of Colombia has resulted in hypersalinization of mangrove soils and the consequent die-off of almost 270 km^2 of mangrove forests during the past 39 years (CARSEA 2007).

After the Indo-Malay Philippine Archipelago, the Caribbean region has the second highest mangrove area loss relative to other global regions, with approximately 24% of mangrove area lost over the past 25 years (Upadhyay et al 2002). Loss of mangroves and seagrass beds results in reduction in the ecosystem service of water purification and nutrient cycling, thus increasing the impact of pollution in adjacent coral reefs and exacerbating their degradation. The coastal protection function of reef, mangrove, and seagrass habitats is increasing in importance in the face of climate change and intensifying extreme weather events.

Drastic changes to reef communities can be caused by invasive alien species. Due to their population explosion and aggressive behavior, the red lionfish can drastically reduce the abundance of coral reef fishes, leaving behind a devastated ecosystem. Albins and Hixon (2008) reported a 79% reduction in forage fish recruitment on experimental patch reefs in the Bahamas during a five week observation period. Aside from the rapid and immediate mortality of marine life, the loss of herbivorous fish also sets the stage for algae to overwhelm the affected coral reefs and disrupt their delicate ecological balance. Baker et al (2002) reported that oyster reefs composed of native eastern oysters (*Crassostrea virginica*) have been displaced by invading green mussels in Tampa Bay. Large green mussel populations may also represent a significant source of competition for planktonic food resources. Potential negative impacts of the green mussel on living marine resources include competition with the oyster fishery, displacement of native mussels, and carriers of diseases and parasites harmful to native species.

Figure 23. Proportion of threatened (Critically Endangered, Endangered, and Vulnerable) mangrove species

<u>Reduction in fisheries productivity and other ecosystem services</u>

Degradation compromises the health and functioning of marine ecosystems and subsequently their ability to provide ecosystem services. Because of the close association of reef fish and invertebrates with their habitat, and high dependence on suitable benthic habitat for reproduction and settling of larvae and juveniles, degradation and loss of essential fish habitat has severe consequences for fisheries productivity. Compelling evidence of the importance of nursery habitat for spiny lobster production has been provided by a number of authors (reviewed in Ehrhardt et al, in press). Ecological studies carried out on spiny lobster habitat in Cuba recognize several fundamental environmental conditions as negatively impacting juvenile recruitment habitat including: 1) decreased amounts of natural and anthropogenic induced nutrients with the advent of dam constructions interrupting the natural runoff of nutrient rich fresh water to the spiny lobster habitat; 2) increased salinity in juvenile habitats affecting larvae and prey species; 3) incidence of major and more frequent hurricanes impacting habitat structure; and 4) significant coastal zone development that impacted inshore-offshore water exchange (Puga et al 2008). Similarly, queen conch (larvae and adults) are particularly sensitive to the quality of their environment, including turbidity and water quality (Appeldoorn et al, in press).

As previously mentioned, the association between certain species of reef fishes, such as the Caribbean parrotfish, and mangroves is so strong that in regions where mangroves have been removed, this species of parrotfish has become locally extinct (Mumby et al. 2004). Yet, few no-take reserves designed to protect coral reef communities have been shown to also protect nearby non-reef nursery habitats (Steneck et al 2009). Although abundant, competent larvae are necessary, this is an insufficient condition for sustaining high rates of demographic connectivity. Increasingly important in coral reef ecosystems is the availability of settlement habitat of adequate quality to facilitate settlement and post settlement success. Studies of corals, lobsters, and fishes suggest that population declines ranging from 50 to 100% can occur when the recruitment potential of benthic habitats is diminished.

Given that ocean currents connect coral reefs to other coral reefs and related marine ecosystems, alteration of ocean currents by climate change could have profound effects on the sustainability and management of reef ecosystems.

Even deep water reef species are impacted by habitat degradation in shallow waters (Heileman, in press). For example, deepwater snappers are distributed over a wide depth range (coastal and surface waters to over 500 m) and diversity of habitats that are vulnerable to degradation from anthropogenic activities. Inshore habitats such as mangrove lagoons, coral reefs, and seagrass beds are known nursery areas for juveniles of many of the species caught on deep slopes and banks as adults. Snappers are also associated with unique and vulnerable deepwater coral (*Oculina*) habitats found in the Caribbean and off the southeastern USA that have been identified as essential fish habitat for Federally managed species.

Socio-economic impacts

The reef ecosystem provides important ecosystem services that are of immense economic value, which are threatened by degradation and loss of these ecosystems. Degradation of coastal ecosystems results in a wide range of adverse socio-economic impacts linked to the tourism and fisheries sectors. The services provided by CLME reef ecosystem are an important source of food, livelihoods, and revenue from fisheries and tourism in the bordering countries, particularly in the Insular Caribbean and coastal communities in South and Central America. Most tourism is concentrated on the coast, a significant portion of which is directly reef-related (dive tourism) with snorkeling and scuba diving among the most popular activities in countries and territories such as the Bahamas, Cayman Islands, Turks and Caicos, Bonaire, and Belize. Money spent by divers and snorkelers supports a range of businesses (e.g. dive shops, hotels, restaurants, and transportation) and in some places directly contributes to the management costs of MPAs through visitor user fees

(Burke et al 2011). Other reef tourists include recreational fishers (e.g. in Bahamas and Cuba), and less directly, beach visitors, in areas where beach sand originates from nearby reefs. As previously mentioned, one of the consequences of habitat degradation is reduced fisheries productivity, the socio-economic impacts of which have been discussed in the section on unsustainable fishing. Conflicts among different groups of users could also arise from habitat degradation (e.g. between fishers and tourists).

Habitat degradation and community modification are likely to have severe socio-economic consequences for those nations and communities that depend heavily on fishing and tourism for their social and economic viability. Tourism revenues are often directly impacted by habitat degradation because of the loss of amenity value for activities such as fishing, swimming, and dive tourism. Habitat degradation represents a loss of income and employment opportunities in the fisheries and tourism sectors in the medium and long-term, and loss of property value.

With limited opportunities for economic diversification in the small islands, habitat degradation can have severe socio-economic consequences for the Insular Caribbean (UNEP 2004a, 2004b). The social and economic vulnerability to coral reef loss as well as the ability to adapt to such loss vary among the countries. As seen in Box 7, among the Caribbean countries and territories in the Insular Caribbean included in a recent study, two are most vulnerable to the effects of coral reef degradation and have low adaptive capacity, while five have high levels of adaptive capacity.

Box 7. Social and economic vulnerability of Caribbean Islands to coral reef loss

Burke et al (2011) examined the potential social and economic vulnerability of coral reef dependent nations to the degradation and loss of reefs. Vulnerability was represented as the combination of three components: exposure to reef threats, dependence on reef ecosystem services (i.e., social and economic sensitivity to reef loss), and the capacity to adapt to the potential impacts of reef loss. Of the 108 countries and territories studied, the most reef dependent were almost all small-island states, many located in the Caribbean. Of these, Haiti and Grenada were found to be the most vulnerable to the effects of coral reef degradation. They have high ratings for exposure to reef threat and reef dependence, combined with low ratings for adaptive capacity. These countries merit the highest priority for concerted development efforts to reduce reliance on reefs and to build adaptive capacity, alongside reducing immediate threats to reefs. Five very highly vulnerable countries and territories–Bermuda, the Dominican Republic, Jamaica, St. Eustatius, and St. Kitts and Nevis– have reefs that are highly or very highly exposed to threat and depend heavily on reef ecosystem services, but also have high or very high levels of adaptive capacity.

Habitat degradation and community modification has also reduced existing income and foreign exchange from other related sectors and inhibited investment. Other economic impacts of habitat and community impacts are degraded coastal land due to loss of physical protection, costs of responding to risks, affected cultural heritage, increased costs of addressing coastal erosion and controlling invasive species and restoration of modified ecosystems. Loss of the coastal protection function of reef, mangrove and seagrass habitats increases the vulnerability of coastal land, infrastructure, and human lives to damaging waves and flooding from sea level rise and storm surges. Other socio-economic impacts of habitat degradation include loss of aesthetic, educational, and scientific values and loss of cultural heritage.

Estimates of economic losses from coral reef degradation in the Caribbean range from US$350 million - 870 million per year by 2015 to coastal countries that currently receive benefits valued collectively at US$3 billion – 4.6 billion per year (Table 13; CARSEA 2007 adapted from Burke and Maidens 2004). This analysis is important in decision making, as it shows that it is in the interest of the countries to conserve their coastal habitats in order to continue to benefit from the valuable ecosystem services.

Table 13. Estimated value of ecosystem services from Caribbean coral reefs, and potential losses from their degradation

Good/service	Estimated annual value in 2000 U.S. $	Estimated future annual losses due to coral-reef degradation
Fisheries	312 million	Fisheries productivity could decline an estimated 30–45% by 2015 with associated loss of annual net benefits valued at U.S. $11–140 million (in constant-dollar terms, standardized to 2000).
Tourism and recreation	2.1 billion	Growth of Caribbean dive tourism will continue, but the growth achieved by 2015 could be lowered by 2–5% as a result of coral-reef degradation, with the region-wide loss of annual net benefits valued at an estimated U.S. $100–300 million (in constant-dollar terms, standardized to 2000).
Shoreline protection	0.7–2.2 billion	Over 15,000 km of shoreline could experience a 10–20% reduction in shoreline protection by 2050 as a result of coral-reef degradation. The estimated value of lost annual net benefits is estimated at U.S. $140–420 million (in constant-dollar terms, standardized to 2000).
TOTAL	3.1–4.6 billion	U.S. $350–870 million

The continued loss and degradation of the region's coastal habitats will impose serious economic consequences for not only the fishing and tourism industry, but the economy of the entire region. The socio-economic costs associated with habitat loss should be estimated in CLME countries and taken into consideration when evaluating different ecosystem management and economic development strategies.

3.2.3. Pollution

Most pollutants can be dispersed throughout the water column from the sea surface to the bottom environment, and their concentrations are not usually recorded separately for the environment of reef and pelagic systems. This tendency presents some difficulty in carrying out analyses of pollution for reef and pelagic systems separately. On the other hand, the impacts on these habitats and on particular organisms are often the subject of more detailed analyses and reporting. For example, nutrients and sediments are known to have severe impacts on coral reefs. For the purposes of these TDAs, an attempt is made to separate pollution in reef and pelagic systems based on reports about the pollutants with the greatest impact in each of these systems. Pollutants that are known to cause severe degradation to reef ecosystems are nutrients, sediments, and hydrocarbons. Because of limited data availability, however, some overlap in the assessment of pollution in the reef and pelagic systems is unavoidable. The following analysis of pollution in the reef ecosystem provides information that is of relevance to both reef and pelagic systems. It first presents information on pollution loads and sources, followed by discussion of the impacts on the environment and living resources, and lastly, socio-economic impacts.

Pollution has significant transboundary implications in the CLME, as a result of the high potential for transport across EEZs in wind and ocean currents and impacts on transboundary living marine resources and ecosystem services. Further, certain contaminants in sea water and marine organisms can directly affect human health through direct contact or consumption. The main pollution problems of the CLME region were identified as: High presence of organic matter and nutrients (phosphorus and nitrogen); elevated concentrations of organic and inorganic toxic substances (oil hydrocarbons and heavy metals), and micro-organisms coming from fecal matter above national and international quality criteria (UNEP-CEP/Cimab 2010). In terms of land-based pollution to the Caribbean Sea, Gil-Agudelo and Wells (in press) and Sweeney and Corbin (in press) reported that sewage (domestic and industrial), heavy metals, hydrocarbons, sediment loads, and agrochemicals (fertilizers and pesticides) are considered the most important. In a regional priority ranking of the categories of the Global Programme of Action for Protection of the Marine Environment from Landbased Sources (GPA) in the WCR, sewage was found to be of first priority, with nutrients, sediments, and persistent organic pollutants (POPs) ranked as second (GESAMP 2001). Despite wastewater treatment facilities in the countries, the poor performance of these systems results in constant discharge of insufficiently-treated domestic wastewater, including sewage, into the sea (Cimab 2010).

A number of pollutants (sewage, POPs, nutrients, sediments, radioactive substances, heavy metals, hydrocarbons, and litter) are addressed under regional and international frameworks such as the Landbased Activities and Sources (LBA) and Oil Spill Protocols of the Cartegena Convention, the GPA, and Stockholm Convention on Persistent Organic Pollutants (mainly focuses on chemicals that undergo long-range atmospheric transport) and the Mercury Convention scheduled for 2013.

Assessment of pollution in the CLME has been conducted by a number of projects, including GIWA (UNEP 2004a, 2004b, UNEP 2006). A more recent, comprehensive assessment of domestic and industrial pollutant loads and watershed inflows into the WCR (UNEP-RCU/CEP 2010) has provided valuable pollution data. This is an update of the assessment carried out in 1994 by the UNEP Caribbean Environment Programme (CEP Technical Report No. 33), and presents a comparative analysis of pollution in these two periods using indicators of biological and chemical oxygen demand (BOD_5 and COD, respectively), total suspended solids (TSS), total nitrogen (TN and total phosphorous (TP). The results are presented for five subregions, four of which are particularly relevant to this TDA (omitted is Sub-region I, the Gulf of Mexico, which includes a relatively small part of the CLME):

Sub-region II Western Caribbean:	Belize, Guatemala, Honduras, Nicaragua, Costa Rica and Panama.
Sub-region III Southern Caribbean:	Colombia, Venezuela, Guyana, French Guiana, Suriname, Aruba and the Netherlands Antilles
Sub-region IV Eastern Caribbean:	Anguilla, Antigua and Barbuda, Barbados, British Virgin Islands, Dominica, Grenada, Guadeloupe, Martinique, Montserrat, St. Martin, St. Lucia, St. Bartholomi, St. Kitts and Nevis, St. Vincent and the Grenadines, U.S. Virgin Islands and Trinidad & Tobago.
Sub-region V North-eastern and Central Caribbean:	Bahamas, Cayman Islands, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico and the Turks and Caicos Islands.

Table 14 shows the total annual loads of $BOD_{5,}$ COD, TSS, TN, and TP discharged into the four sub-regions of the Caribbean Sea from urban and industrial activity and watersheds inflows according to the available information (UNEP-RCU/CEP 2010). The wastewater flow to the Southern Caribbean is the highest, perhaps indicative of higher rainfall in watershed inflows and inappropriate land-use and management. In the other sub-regions, the flow discharged to the WCR behaves according to the size of the drainage area. As seen in Table 14, the largest total contribution of nutrients (TN and TP) comes from the Southern Caribbean (sub-region III), with 644,000 and 125,000 tonnes per year, respectively. Much of this could be attributed to the Magdalena River of Colombia, which contributes the highest load of nutrients to the Caribbean Sea (CARSEA 2007). Note that total phosphorus inflow from the Orinoco River was not included in the overall nutrient loading assessment due to a lack of information. The smallest nutrient loading comes from sub-region IV (Eastern Caribbean) with only 3,000 tonnes TN yr^{-1} and 1,000 tonnes TP yr^{-1} due to the smaller area and smaller size of the Sub-region's watersheds. The largest TSS contribution also comes from the Southern Caribbean (sub-region III), with over 200 million tonnes per year. The Magdalena River might be responsible for a large fraction of this load, with an annual contribution of sediments of 144 million tonnes per year (CARSEA 2007). The lowest contribution comes from the Eastern Caribbean. BOD_5 and COD show similar trend among the sub-regions, with the highest contributions coming from the Southern Caribbean sub-region and the lowest from the Eastern Caribbean.

Table 14. Wastewater flow and total annual pollution loads discharged into the Caribbean Sea

Sub-region	Drainage area (km^2)	Waste-water flow [1] ($m^3.sec^{-1}$)	Average annual load ($tonnes.yr^{-1}$) x 10^3				
			BOD_5	COD	TSS	TN	TP
Western Caribbean	291,439	3,004	427	1,851	5,819	15	5
Southern Caribbean	1, 278,743	3,364	3,364[2]	14,670 [2]	202,383	644	125 [2]
Eastern Caribbean	105,242	1,004	210	389	56	3	1
North-east and Central	378,871	3,055	722	2,780	7,688	36	13

[1]The industrial wastewater flow is not included because of the lack of information.
[2]Organic loadings and phosphorous from Rio Orinoco watersheds are not included because of the lack of information.

Domestic, industrial, and watershed loads of each of the five pollutants in the four sub-regions are compared in Table 15. These same data are given by countries in Annexes 2, 3 and 4, respectively. By far, the greatest total loads are those of TSS, followed by COD and BOD from watershed run-off (for all four sub-regions combined), all coming from sub-region III. Similarly, the highest nutrient loads (TN and TP) also come from watershed run-off in sub-region III. The next highest loads are of COD of domestic and industrial origin (sub-regions V and IV, respectively) and BOD of industrial and domestic origin (sub-region IV and V, respectively).

Fertilizer, agro-chemical, and manure runoff from agricultural lands in upstream coastal areas of CLME countries are the most significant sources of nutrients to the marine environment (particularly nitrogen and phosphorus) from non-point sources. These contaminants are particularly prevalent because important crops like sugar cane, citrus fruits, bananas, grains, and coffee require large amounts of fertilizers and pesticides. In 2005, CLME countries used more than 1.7 million tonnes of fertilizers (UNEP-RCU/CEP 2011). Sediments, sewage, and nutrient pollution from agricultural sources constitute the largest pollution threat to critical coastal habitats. It is therefore essential for WCR countries to prevent, reduce, and control these sources of pollution under the LBS Protocol and other measures such as IWCAM in order to protect human health and living marine resources.

Table 15. Pollutant loads (tonnes .yr^{-1}) from domestic, industrial, and river basins by sub-regions in WCR

(Compiled from UNEP-RCU/CEP 2010)

Source	**Pollutant**	**Sub-regions**				**Total**
		II	**III**	**IV**	**V**	
Domestic	BOD	14,489	104,848	11,916	146,375	**277,628**
	COD	33,027	240,741	27,154	336,413	**637,335**
	TSS	13,353	99,888	10,960	140,055	**264,256**
	TN	1,619	12,416	1,324	17,465	**32,824**
	TP	552	4,497	450	6,370	**11,869**
Industrial	BOD	9,954	34,048	197,062	52,117	**292,511**
	COD	21,807	69,101	353,883	109,328	**553,317**
	TSS	5,983	86,593	42,382	8,525	**143,456**
	TN	659	10,750	1,326	1, 915	**14,562**
	TP	263	663	631	1,287	**2,539**
Watershed run-off	BOD	403,000	3, 221,000	1,700	524,000	**4,000,000**
	COD	1,796,000	14,350,000	8,000	2,335,000	**18,000,000**
	TSS	5,800,000	202,283,000	2,600	7,540,000	**215,438,000**
	TN	12,700	620,000	200	16,500	**656,000**
	TP	4,300	120,000	40	5,600	**148,000**

Comparison of total pollution loads in the 1994 and 2010 reports is shown in Box 8. Domestic and industrial pollution loads have apparently decreased, although this might be partly caused by differences in methodologies. Notable is the increase in loads from watersheds (nutrients and sediments), which could severely affect coastal ecosystems. Watersheds inflows from sub-region III (Southern Caribbean) show increases in average annual sediment loads of 15%. The observed increase arises from growing urban-industrial and agricultural development (although several minor watersheds were not assessed due to the lack of information).

Box 8. Changes in pollution loads discharged to the Caribbean Sea reported in 1994 and 2010

- Reductions in domestic pollutant loads, in particular in nutrients, despite the gradual population increase due probably to a larger control of sewage discharged and the differences among methodologies used in both reports.
- A strong decrease in industrial pollutant loads, despite the progressive industrial development, which could be due to differences in the methodologies used in both reports and improved waste treatment capacities in industries.
- Discharges from watersheds show an increase in pollutant loads, characteristic of a larger exploitation in the basins (and probably to differences in methodology).
- Projected change in domestic pollutant loading in years 2015 and 2020 based on current trends assuming efforts are taken to meet the UN Millennium Development Goals, shows only slight increases, despite the estimated population increase.

A spatially explicit model (Nutrient Export from Watersheds – NEWS) that relates human activities and natural processes in watersheds to nutrient inputs to coastal systems throughout the world has been used to examine the relative magnitudes and distribution of dissolved inorganic nitrogen (DIN) loading from watersheds to LMEs globally (Seitzinger and Lee 2008). Results showed that the CLME receives substantial DIN loads, between 750,000 to 1 million tonnes per year (Figure 24).

The WRI Watershed Analysis in the Mesoamerican Reef quantifies sediment and nutrients coming from over 400 watersheds that discharge along the Mesoamerican Reef in sub-region II (Western Caribbean) by using the Non-point Source Pollution and Erosion Comparison Tool (Burke and Sugg 2006). The results provide a preliminary overview of regional patterns of sediment and nutrient runoff and delivery, and indicate how human alteration of the landscape can influence these patterns. In the Mesoamerican region, over

300,000 hectares of land is used for production of banana, oil palm, sugar cane, citrus, and pineapple crops. Eroded sediments as well as the residues of fertilizer and pesticides used in these areas drain through the rivers and streams and enter coastal waters along the Mesoamerican Reef.

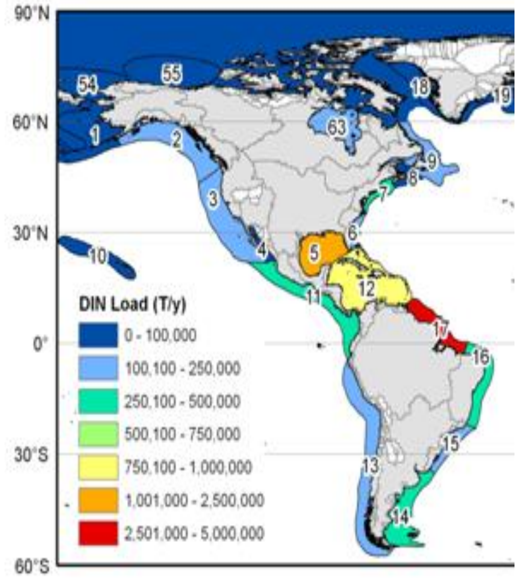


Figure 24. DIN inputs to the CLME from land-based sources predicted by the NEWS model.

(Watersheds discharging to LMEs are grey)

Figure 25 shows the results with a visual estimate of sediment discharges and nitrogen into the Mesoamerican Reef. The model suggests that over 80% of sediment originates in Honduras, while 17% of sediment originates in Guatemala. Relatively minor percentages come from Belize and Mexico. Honduras is also the largest source of nutrients (55% of N and 60% of P), while Guatemala contributes about one-quarter of all N and P in these watersheds. Belize contributes about 12-13% of both N and P, while Mexico is estimated to contribute about 5% of the total of these nutrients from all modeled watersheds.

A similar approach was used to assess the sediment loadings for sub-regions IV (Eastern Caribbean) and V (Northwestern and Central) by the Regional Activity Center-Cimab in 2008 (CATHLAC/Cimab 2008). The sediment load from sub-region V (Northwestern and Central Caribbean) is much greater than that of sub-region IV, particularly due to the sedimentary loads from Haiti, Dominican Republic and Cuba, although seven countries were not assessed due to the lack of information (Figure 26). The sediment load from sub-region IV (Eastern Caribbean) comes particularly from Martinique, St. Kitts and Nevis, Dominica and Guadalupe. Deforestation, mining, and poor land use practices have led to a great increase in the sediment loads in coastal areas in both the Insular Caribbean and Central-South American sub-regions.

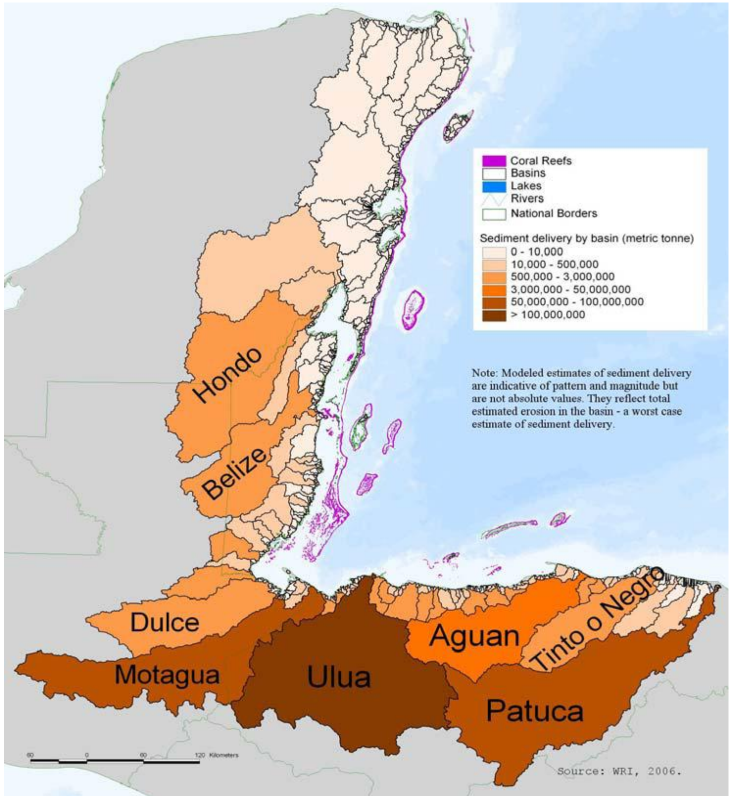


Figure 25. Sediment delivery to the Mesoamerica Reef from adjacent watersheds

The CLME is also affected by pollutants and microbes arising from outside the region. A notable example is Sahara dust that reaches over the Caribbean in air currents (Figures 27 and 28). This dust cloud is thought to contain POPs and pathogens, the latter of which have affected Caribbean coral reefs. Peak years for dust deposition were 1983 and 1987. These were also the years of extensive ecological change on Caribbean coral reefs (Source: USGS 2000)

In general, the major concern of contamination from petroleum hydrocarbons in the Caribbean region is from accidental events, i.e., major oil spills, since operational discharges are well regulated in general. The potential for oil pollution has been classified as severe in the area by GIWA (UNEP 2006). Hydrocarbon pollution is discussed in greater detail in the following pelagic ecosystem section.

The CLME region is also impacted by extra-regional influences (discussed in the pelagic ecosystem section).

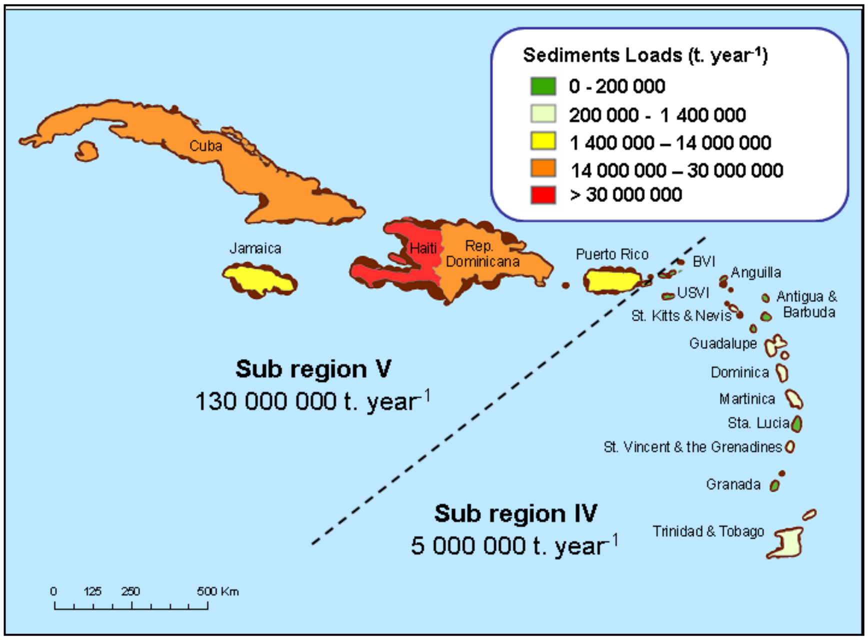


Figure 26. Relative sediment loads (t.yr-1) from non-point sources into sub-regions IV and V

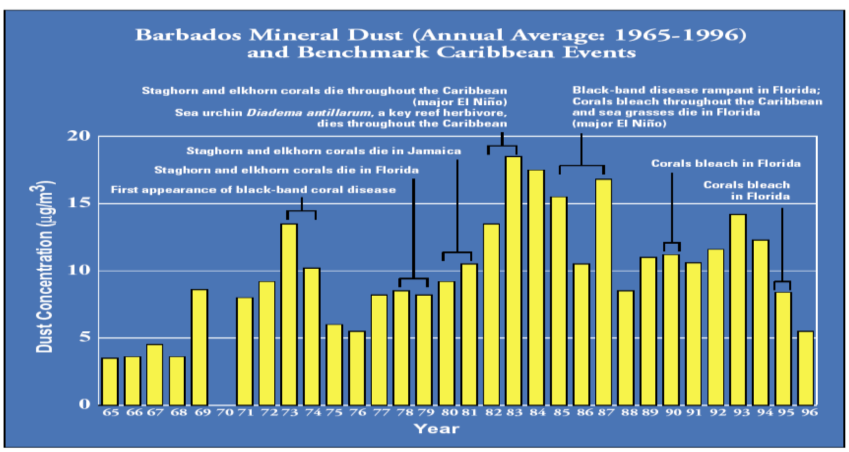


Figure 27. Overall increase in African dust reaching Barbados since 1965

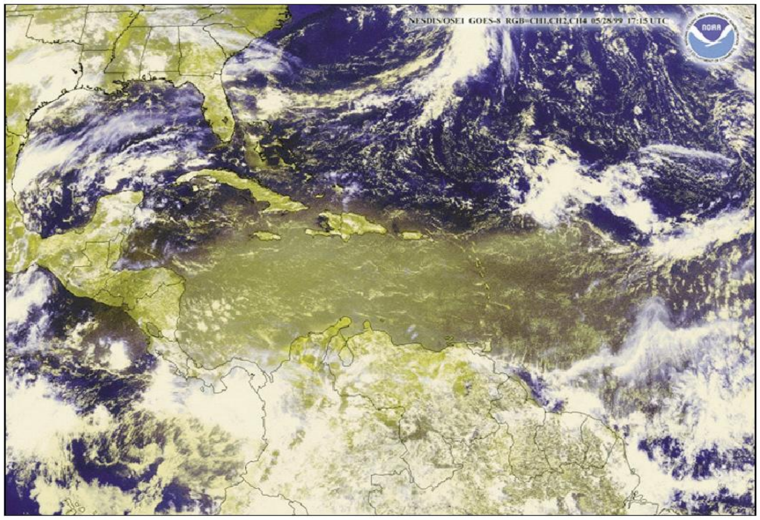


Figure 28. May 28, 1999 satellite image of SE United States, Central America, and the Amazon region

The major environmental impacts of pollution of the reef ecosystem include:

i. Deterioration of environmental quality;

ii. Threats to living marine resources.

<u>Deterioration of environmental quality</u>

Pollution reduces the quality of the marine environment, including in places far from the source. This can degrade living marine resources and pose threats to human and animal health by the introduction of pathogens. Several coastal pollution hotspots have been identified in the region, which show poor environmental quality resulting from a range of substances (Cimab 2010). These include heavily contaminated bays such as Havana Bay (Cuba), Santo Domingo (Dominican Republic), Kingston Harbour (Jamaica), Bluefields Bay (Nicaragua), Port of Point Lisas (Trinidad and Tobago), Cienaga Grande Santa Marta (Colombia), and Gulf of Cariaco (Venezuela). Under the GEF Integrated Watershed and Coastal Area Management (IWCAM) project in Caribbean SIDS, a number of other coastal hotspots were identified: St. John's Harbour (Antigua and Barbuda); Haina river basin and coastal area (Dominican Republic); Elizabeth Harbour in the Exuma Keys (Bahamas); and Buccoo Reef (Tobago).

Sewage is regarded as one of the most important and widespread causes of deterioration of the coastal environment in the Caribbean. While sewage contains a number of substances, of particular concern is its high content of nutrients and microbes. In the WCR, the single largest source of nutrient pollution comes from domestic/urban sewage (UNEP-RCU/CEP 2011). In a regional overview of land-based sources and activities affecting the marine, coastal, and associated freshwater environment in the WCR, high nutrient levels (including from sewage) were of concern in coastal areas of several Caribbean SIDS (UNEP-RCU/CEP 1998). Nutrients have given rise to widespread eutrophication (over-enrichment of water by nutrients such as nitrogen and phosphorus). Suspended sediments also impair water quality by blocking light penetration and introducing attached chemical compounds and pathogens. This can have serious consequences for reef living marine resources (see following section).

Although organochlorides are banned throughout most of the Caribbean, sites with heavy organochloride pollution loads have been reported, for example, Kingston Harbour and Hunt's Bay in Jamaica (Dasgupta and Perue 2003). Studies in the Caribbean documented in UNEP/GEF (2002) showed that POPs have been detected in sediments in Portland and Kingston Harbour, the southwest coast of Cuba, and coastal areas of St. Lucia.

Heavy metals and substances like tributyl tin are found near cities, ports, and industrial developments across the region, including in remote areas (Fernandez et al 2007). Guzmán and García (2002) evaluated Hg concentrations along the Caribbean coast of Central America, both in sediments and coral skeletons. Widespread Hg concentrations in the regions, in sediments (average 71.3 μg/l) and in coral skeletons (average 18.9 μg/l), suggests that these pollutants are being carried along the region by ocean currents, with high concentrations of this metal being found even in 'pristine' reefs.

Threats to living marine resources

Deterioration of environmental quality can impair the functioning of coastal ecosystems and affect the health of living marine resources. Coral reefs are highly threatened by pollution throughout the WCR, including reefs in the Mesoamerican area (Belize, Guatemala, Honduras and a small part of Mexico), Costa Rica, and Panama in sub-region II (Western Caribbean), Colombia and Venezuela in sub-region III (Southern Caribbean), some islands of the Lesser Antilles in sub-region IV (Eastern Caribbean), and most countries of the Greater Antilles in sub-region V (Northwestern and Central Caribbean). Pollution can kill or impede the growth of coral, mangrove and seagrass and make them more vulnerable to diseases. Sedimentation and pollution from both land and marine based sources pose high levels of threat to coral reefs in the Caribbean, with pollution from inland sources threatening about one-third of Caribbean coral reefs (Figure 29; Burke and Maidens 2004).

High nutrient inputs have promoted hotspots of eutrophication, increased algal and bacterial growth, degradation of seagrass and coral reef habitats, changes in community structure, decreased biological diversity, fish kills, and oxygen depletion in the water column in some localized areas throughout the region (UNEP 2004a, 2004b). Elevated nutrient inputs into coastal areas have also contributed to overgrowth of coral reefs by algae in many localities. This has been compounded by the reduced abundance of algal grazers on many reefs throughout the region, as previously discussed.

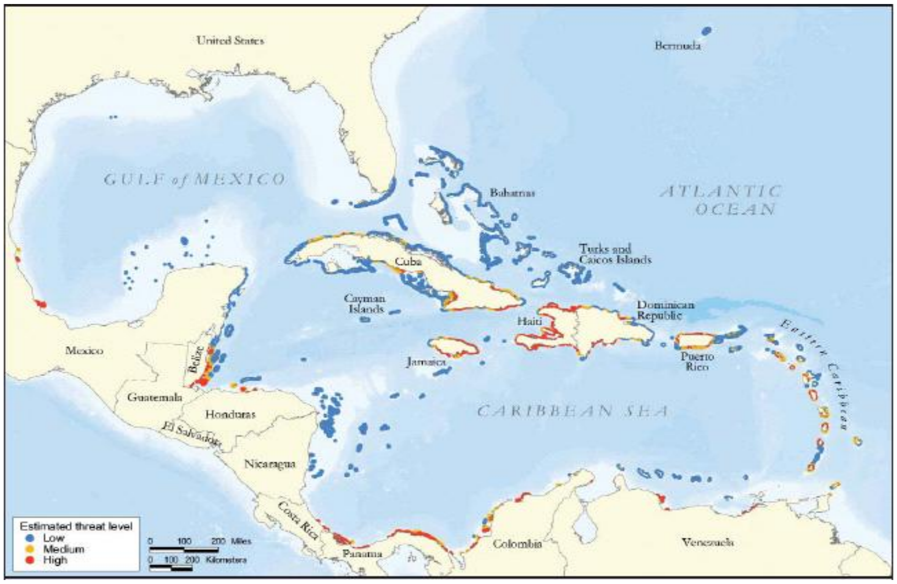


Figure 29. Threat to coral reefs by sedimentation and pollution from inland sources in the Caribbean

Smothering of coral reefs, seagrasses, and associated filter feeders and other benthic organisms by high sediment loads is of concern throughout much of the region. Damage caused to coral reefs by sedimentation has been documented in the coasts of Panama, Costa Rica, and Nicaragua, among other localities (Burke and Maidens 2004). Sediments from the Magdalena River is thought to be responsible for most of the observed reef mortality in the El Rosario Islands of Colombia, where dead coral cover has reached 58% (CARSEA 2007). The impact of sedimentation in coastal areas is exacerbated by the destruction of mangrove forests and seagrass beds, which act as natural filters, reducing the sediment load in freshwater runoff before it enters the sea.

Some pollutants can have direct impacts on the living marine organisms themselves because of their toxicity. For example, herbicides in agricultural runoff can cause damage to seagrass beds. Oil spills are known to have adverse effects on the ecology of coastal ecosystems, particularly coral reefs, mangroves as well as fish and shellfish populations.

Pesticides present in the dust cloud reaching the Caribbean and southern USA from North Africa may affect the marine environment through direct fertilization of benthic algae by iron or other nutrients and by broadcasting of bacterial, viral, and fungal spores. A serious but unseen threat to living marine resources is the bioaccumulation of pollutants such as POPs and heavy metals in their tissue. This is of great concern in higher trophic level animals and ultimately humans, due to the bio-magnification of these pollutants in the food chain.

The occurrence of coral-reef diseases may be partially due to pathogenic bacteria associated with an increasing intensity of Sahara dust over the last two decades. There is mounting evidence to suggest that some of the declines occurring on Caribbean coral reefs may be linked to African dust. The 1983 die-off of the long-spined sea urchin and the beginning of the Plague II outbreak in 1997 followed within months of peak dust events in the region. The strongest evidence thus far is that *Aspergillus sydowii*, a known fungal disease affecting sea fans, has been identified in its active pathogenic form in air samples collected during Saharan dust events in the US Virgin Islands, but not during clear atmospheric conditions (Garrison et al. 2003).

Socio-economic consequences

The socio-economic consequences of pollution vary from slight to severe in the region, as found by GIWA. These include a decrease in the value of fisheries products through contamination, and loss of economic and aesthetic value of coastal areas. HABs are frequently the cause of very serious human illness when the biotoxins produced are ingested in contaminated seafood. The illnesses most frequently associated with marine biotoxins include paralytic shellfish poisoning and ciguatera poisoning. High bacterial counts have been detected in some bays in the region (UNEP 2004a), especially where there are large coastal populations and high concentration of boats. Microbiological pollution from sewage is also a threat to human health and in some areas downstream coastal communities have a high prevalence of gastrointestinal and dermal ailments (UNEP 2006). Sewage discharge into coastal areas also endangers public health from the consumption of seafood with different degrees of contamination.

Heavy metals and chemical and organic compounds released into the environment by industrial and agricultural activities present a permanent threat to human health and living marine resources. Bioaccumulation of some pollutants such as POPs and heavy metals in the tissue of marine organisms that are consumed by humans can also have serious impacts on human health.

Pollution has also diminished the aesthetic value of some areas, impacting on recreational activities and reducing revenue from tourism (UNEP-CEP/RCU 1997). Oil spills can affect the quality of the region's beaches and may have significant negative impacts on the economies of countries relying on tourism. Tar balls are known to accumulate on the region's beaches. They are composed of a mixture of hydrocarbons and saltwater, and are able to drift for long distances. Loss of habitats such as coral reefs could also affect tourism. The economic cost of addressing pollution (e.g. clean up of oil spills, adoption of new technologies) and of medical treatment of pollution-related illnesses could be very significant. Data (or access to data) on the socio-economic impacts of pollution is very limited in the region.

4. PELAGIC ECOSYSTEM AND SOCIO-ECONOMIC SETTING OF THE CLME

4.1. Fishery ecosystem oriented setting

4.1.1. Pelagic ecosystem

For the purposes of the CLME TDA, the pelagic ecosystem is considered to be restricted to the epipelagic zone of the ocean. This is the euphotic zone that extends from the surface to a depth of about 200 m. This zone has the highest levels of sunlight, photosynthesis, and dissolved oxygen, and is where almost all ocean life is found. On the whole, the Caribbean Sea is mostly comprised of clear, nutrient-poor waters. While it does not have the structural complexity of coral reefs and other coastal habitats, the pelagic environment is not homogenous. It can be characterized by differences in abiotic and biotic factors (temperature, oxygen, salinity, transparency, light intensity) and the presence of phytoplankton, zooplankton, prey and predators. Areas of high productivity within the pelagic zone include coastal upwelling and oceanic fronts.

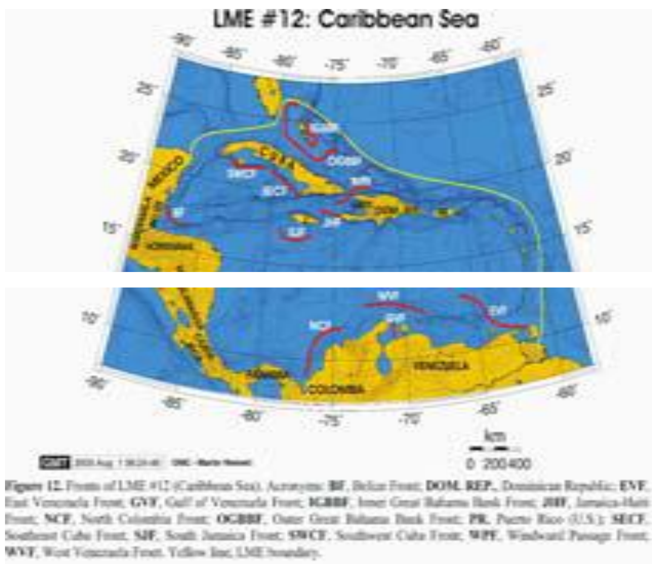


Figure 30. Fronts of the Caribbean Sea LME

BF, Belize Front; DOM.REP., Dominican Republic; EVF, East Venezuela Front; GVF, Gulf of Venezuela Front; IGBBF, Inner Great Bahama Bank Front; JHF, Jamaica-Haiti Front; NCF, North Colombia Front; OGBBF, Outer Great Bahama Bank Front; PR, Puerto Rico (U.S.); SECF, Southeast Cuba Front; SJF, South Jamaica Front; SWCF, Southwest Cuba Front; WPF, Windward Passage Front; WVF, West Venezuela Front. Yellow line, LME boundary (Belkin et al 2009).

Oceanic fronts and eddies affect LME productivity and are an important feature of the pelagic system. These features are determined by large scale and mesoscale current patterns. Fronts in the southern Caribbean Sea (Figure 30) are generated by coastal wind-induced upwelling off northeast Venezuela and Colombia (Belkin et al 2009), which promotes high primary production in this area. A 100-km long front dissects the Gulf of Venezuela, likely caused by the brackish outflow from Lake Maracaibo combined with coastal upwelling. Two shelf-break fronts off Cuba encompass two relatively wide shelf areas off the southern Cuban coast, both best developed in winter. The Windward Passage Front between Cuba and Hispaniola separates the Atlantic waters moving into the Caribbean in the western part of the passage from the Caribbean outflow waters heading eastward. A 200-km-long front in the Gulf of Honduras peaks in winter, likely related to a salinity differential between the Gulf's apex and offshore waters caused by high precipitation in southern Belize (Heyman and Kjerfve 1999).

The pelagic realm provides important habitats for adult and other life history stages of living marine resources (including of reef species) as well as lower trophic levels (phyto and zooplankton) that are important in ocean food webs. Mohammed et al (2008) provided a comprehensive description of the major groups of pelagic animals in the Lesser Antilles under the Lesser Antilles Pelagic Ecosystem Project (LAPE). A total of 28 functional groups of macrofauna were identified, comprising over 100 species among which are seabirds, small and large pelagic bony fish, pelagic sharks, marine mammals, turtles and invertebrates (squid and crustaceans). While sea turtles inhabit the pelagic system, for the purposes of this TDA they are considered reef-related and have been dealt with in the previous section on the reef ecosystem.

During hydroacoustic and pelagic trawl surveys, high concentrations of juveniles of large pelagic species as well as of reef species were observed in offshore pelagic areas beyond the shelf area (Melvin et al. 2007). Also found are mesopelagic fish that perform large vertical migrations, spending daytime in the mesopelagic zone (200 to 1000 m) and rising to the upper 200 meters of the ocean at night to feed. Small pelagic fish as well as invertebrates such as squid and pelagic crabs are important prey species in the pelagic system, which also provides an important source of food for many seabirds in the form of small schooling pelagic fish. Therefore, the pelagic ecosystem has important trophic and ontogenetic linkages with the reef system, the deeper oceanic zones as well as with the land (e.g. through seabirds and turtles that nest in coastal areas and beaches).

4.1.2. Pelagic ecosystem services

The major categories of ecosystem services are described in the reef ecosystem section, and are also pertinent to the pelagic ecosystem. This realm provides a range of valuable ecosystem services, some examples of which are given in Table 16. Among these, the provisioning service (especially fish resources), cultural service (recreational and tourism value) and supporting service (habitat value and transport of eggs and larvae, including of reef species) are of particular relevance to the CLME project.

Information on the economic value of ecosystem services of the pelagic system was not available at the time of preparation of this report. However, the fisheries alone account for a significant contribution as the large pelagic resources are of very high economic value.

Table 16. Ecosystem goods and services of the pelagic ecosystem

PELAGIC ECOSYSTEM SERVICES			
Provisioning	**Regulating**	**Cultural**	**Supporting**
• Fish for food and recreational fishing • Medium for shipping • Energy generation (waves) • Pharmaceutical products	• Climate regulation	• Recreational and tourism value (recreational fishing, sailing, etc) • Knowledge systems and educational value • Spiritual and inspirational value	• Habitat for fish, including critical habitat for eggs and larval stages of fish and shellfish • Transport of eggs and larvae to feeding and recruitment grounds

A brief description of the major pelagic groups that are of commercial importance in the CLME follows.

- ***Small coastal pelagic species***

This group consists of an enormous diversity of species, and includes jacks (*Caranx* spp., *Selar crumenophthalmus*), scads or robins (*Decapterus* sp.,), ballyhoo (*Hemirhamphus* sp.), herrings (*Harengula* spp, *Sardinella* spp.) and anchovies (*Anchoa* spp.). These species occur on the shelf areas and support important local fisheries (for bait and human consumption) that deploy beach seines and other encircling gears. In St. Vincent and the Grenadines, for example, small coastal pelagics make up about 45% of total landings (FAO Fishery Country Profile). Some of these species also constitute a major food source for larger pelagic species. An important group of small pelagic species is flyingfish (Exocoetidae), 11 species of which have been reported in the eastern Caribbean. Three species of flyingfish are common in the southeastern Caribbean (*Hirundichthys affinis*, *Parexocoetus brachypterus* and *Cheilopogon cyanopterus*), of which *H. affinis* (fourwing flyingfish) is the most important in the pelagic fisheries in the southeastern Caribbean. While the focus of the pelagic ecosystem TDA is on the large pelagic fish resources, the flyingfish is also of interest. This species is both a key forage species and an important fishery resource for both bait and human consumption. It is closely associated ecologically and technologically with the dolphinfish.

- ***Large pelagic species***

The large pelagic resources form the basis of very valuable commercial fisheries in the CLME region. They are categorized into two groups: coastal pelagic species and oceanic pelagic species. These species are top predators in the ocean environment, and so their health and survival are closely linked to the health and survival of their prey species. Prey species are often smaller-sized pelagic fishes that are themselves the target of other fishing operations. As such, there is also a close 'trophic' link between the fisheries that harvest these large predators and those that harvest their prey. Additionally, fishing gears used to target large pelagic fish resources, such as longlines, can also catch other living marine resources such as sea turtles, sea birds and various other species of fish as bycatch. Hence the impacts of fishing activities directed at large pelagic fish resources extend beyond these resources and are linked to other parts of the ecosystem (Singh-Renton et al, in press).

The large coastal pelagics are largely confined to the WECAFC area and are thought to be more local in distribution than oceanic pelagics, occurring primarily on island or continental shelves. Within this group are medium sized and large sized coastal predators. The former includes several species of needlefish (Belonidae), barracudas (Sphyraenidae), jacks or *jurels* (*Caranx hippos, C. latus*), pompanos (*Alectis ciliaris* and *Trachinotus* spp.), rainbow runner (*Elegatis bipinnulata*), leatherjacks (*Oligoplites* spp.), amberfish (*Seriola* spp.), Atlantic bonito (*Sarda sarda*), frigate and bullet tunas (*Auxis* spp.) and little tunny (*Euthynnus alletteratus*).

Among the larger coastal pelagics are blackfin tuna (*Thunnus atlanticus*), dolphinfish (*Coryphaena hippurus* and *C. equiselis*), mackerels (serra Spanish mackerel *Scomberomorous brasiliensis,* king mackerel *S. cavalla,* cero mackerel *S. regalis,* Spanish mackerel *S. maculatus*), and cobia *(Rachycentrum canadum).* A number of coastal shark species are also included such as smalltail shark (*Carcharhinus porosus*) and Caribbean sharpnose shark (*Rhizoprionodon porosus*).

The oceanic pelagic resources are Highly Migratory Species and Straddling Stocks (HMS & SS), moving through all or most of the EEZs and extending into the High Seas. The dynamics of their movements is, however, only poorly understood. Among the oceanic pelagic species of major commercial importance are yellowfin tuna (*Thunnus albacares*), albacore (*T. alalunga*), bigeye tuna (*T. obesus),* skipjack tuna (*Katsuwonus pelamis*), swordfish (*Xiphius gladius*), sailfish (*Istiophorus platypterus*), Atlantic blue marlin (*Makaira nigricans),* Atlantic white marlin (*Tetrapturus albidus),* and wahoo (*Acanthocybium solandri*).

The Caribbean Sea is an important spawning ground for some of these oceanic pelagic species. For example, the central and northern Caribbean Sea and northern Bahamas have historically been known as the primary spawning area for blue marlin in the western North Atlantic. Recent reports show that blue marlin spawning can also occur in an offshore area near Bermuda. Yellowfin tuna spawning occurs in the southeastern Caribbean Sea, Gulf of Mexico, and off Cape Verde, although the relative importance of these spawning grounds is unknown (ICCAT, http://www.iccat.int/en/assess.htm).

A number of oceanic shark species are also included in this group, such as blue shark (*Prionace glauca*), porbeagle (*Lamna nasus*), longfin mako (*Isurus paucus*), shortfin mako (*I. oxyrinchus*), threshers (*Alopias vulpinus* and *A. superciliosus*), tiger shark (*Galeocerdo cuvier*), oceanic whitetip (*Carcharhinus longimanus*), blacktip shark (*C. limbatus*), silky shark (*C. falciformis*), spinner shark (*C. brevipinna*) and the hammerhead sharks (*Sphyrna* spp.). Most species of oceanic sharks may also be found on the continental shelf and shallow coastal areas during feeding and reproduction (Mohammed et al 2008).

- ***Marine mammals***

Marine mammals are an integral part of the marine and coastal fauna of tropical and sub-tropical waters of the Caribbean Sea. These animals also have significant economic, aesthetic and amenity value to the peoples of the region. At least 34 species of marine mammals are known to inhabit the waters of the Caribbean Sea, seasonally or year-round (UNEP-CEP/RCU 2001). Some species of cetacean may be resident in the Caribbean year-round, while others, such as the humpback whale, are known to engage in long-distance migrations between summer feeding grounds in higher latitudes and winter breeding grounds in the tropical waters of the Caribbean. There is a limited fishery for marine mammals in the region, mainly in the Lesser Antilles.

4.1.3. Description of the current pelagic fisheries/mariculture and existing baseline

The CLME countries exploit a wide array of pelagic species, from small coastal pelagic fish, large coastal and oceanic pelagic fish and sharks, and to a limited extent, marine mammals. These resources represent a very important and valuable sector in the region, contributing to food, employment, income and foreign exchange in the various countries. With the overfishing and decline of reef and inshore fisheries, the pelagic resources have become the focus of fisheries expansion in the region, particularly for large pelagic species.

Prior to the latter part of the 20th Century, Caribbean fisheries were limited to subsistence and artisanal levels. In the 1970s, especially after the declaration of the Exclusive Economic Zone (EEZ) regime, several countries (e.g. Mexico, Cuba, Colombia, Nicaragua, Panama, and Venezuela) implemented government-sponsored fisheries expansion programmes, with focus on the offshore resources. Some of these countries such as Trinidad, Colombia, Cuba, Mexico, and Nicaragua even established government fishing companies that promoted fishing industry expansion (Christy 1997). This expansion was accompanied by subsidization programmes involving loans for vessels, gear purchases, and fuel tax rebates in several Caribbean islands (Mohammed et al 2003).

The focus of this TDA is on the large pelagic species that are of transboundary and economic significance in the CLME. These include those species regularly assessed by ICCAT (albacore, yellowfin tuna, bigeye tuna, skipjack, bluefin tuna, swordfish, blue marlin, white marlin, sailfish, blue shark and mako shark) and those species that have not been assessed by ICCAT either because of their low priority (small tunas, spearfishes, mackerels and other sharks) or because they do not fall under ICCAT's management, such as dolphinfish and carangids.

As in the reef fisheries, the numbers of boats and persons employed in the pelagic fisheries are difficult to discern for the entire CLME. Based on the dominant species in the catch by country, however, it is possible to determine if the country in question is targeting reef or pelagic resources. In most cases, country level socio-economic data are aggregated for all fisheries combined, which makes it impossible to separate the data for each of the two ecosystems. For a few countries, data on the number of boats are available separately for large pelagic species (as described below). At the regional level, however, the majority of the boats and persons employed are found in the artisanal, inshore sector, with a smaller proportion in the large pelagic sector.

The following is a brief description of the major fisheries for large pelagic species in the CLME region.

Large oceanic pelagic fisheries

- ***Large tunas***

Apart from Venezuela (and the USA, which has some catches in the western Tropical Atlantic), the major fishing countries for large pelagic resources are in the Lesser Antilles, most of which are members of the CARICOM Regional Fisheries Mechanism (CRFM): Barbados, Grenada, St. Lucia, and Trinidad and Tobago. Substantial catches of large pelagic species are also taken by Martinique and Guadeloupe.

Caribbean governments and fishing industry have spent considerable effort over the last 15 - 20 years to build the region's capacity for exploiting large pelagic resources, especially through the development of longlining for oceanic pelagic species. This growth is most notable in the Lesser Antilles where the resource is known to be available. The sub-region's fishing fleets have traditionally harvested large pelagic fish resources for centuries. Dolphinfish, wahoo, and the smaller shelf-associated tuna species such as skipjack and blackfin tuna were usually caught opportunistically on single-hook trolling gear on fishing trips for small coastal pelagics (CRFM 2008). The exception was the Barbadian fishing fleets, which have always focused on the pelagic fisheries, particularly flyingfish and the associated large pelagics, principally dolphinfish and wahoo.

Several countries now operate significant numbers of medium (7–15 m) and large (>15 m) longliners. Barbados has 36 registered longliners, Belize has 14 (all over 24 m LOA), St. Vincent and the Grenadines 34 (19 of which are over 24 m LOA), and Trinidad has 24 (CRFM 2009). In addition, Grenada has over 200 long liners and other countries such as Dominica, St. Lucia, and Guadeloupe have smaller numbers. Another large fleet of longliners operating in the southern Caribbean and offshore of the Guyana area is the Venezuelan industrial longline fleet (Die 2004). Most of the operations of this fleet occur in the Caribbean area of Venezuela, although operations extend east of Barbados and all the way down to 5°S. Purse-seine effort is restricted to the area around Venezuela. Fleets from distant water fishing nations are also known to exploit the large oceanic species, particularly on the High Seas. In recent times, the Japanese and Taiwanese longline fleets have operated much less frequently in the waters of the Caribbean than they did prior to the 1990s, and the USA longline fleet has also reduced its presence after 1996.

In most countries fishing for large pelagics is done only within territorial waters or the EEZ, although a few countries fish in adjacent EEZs and on the high seas. The fisheries for the highly migratory species are seasonal, and fishers may shift to other species (including reef fish) in the 'off-season' for these migratory resources. Significant improvement in technology has resulted in the use of larger ice-boats and with diesel inboard motors providing the capacity to undertake multi-day fishing trips. Longliners primarily target tunas (especially yellowfin) and swordfish for export, and the catch may be trans-shipped in other countries (Box 9).

Box 9 . Longline operations of four Caribbean countries

Longline operations of four Caribbean countries

During 2003-2007, the average reported annual landings of the Trinidad and Tobago fleet of 24 longliners were around 500 mt. Longline fishing vessels of Belize and St. Vincent and the Grenadines, which are licensed to operate within the ICCAT Convention Area, offload or trans-ship their catches at trans-shipment ports in Trinidad and Tobago (Port of Spain and Chaguaramas). At these ports, catches of target species such as large tunas and swordfish are usually trans-shipped and exported to the USA either chilled or frozen, while bycatch species such as billfish are sold locally or shipped to neighbouring islands like Barbados. In the period 2000-2007, the total amount of major tuna species (yellowfin tuna, albacore, bigeye tuna, important billfish, such as blue marlin, white marlin, sailfish and swordfish) trans-shipped in Trinidad and Tobago by Belizean and St Vincent vessels amounted to 32,500 mt, or an average of 4,000 MT a year. During 2000-2007, reported landings of the Barbados longline fleet of major tuna species were 1,789 mt (an annual average of about 220 mt). The main landing site for these vessels is the Bridgetown Fisheries Complex.

(CRFM 2009)

Of the species regularly assessed by ICCAT, those with the largest landings in the CRFM countries[13] are yellowfin tuna, albacore tuna, skipjack and sailfish (Figure 31, Table 17) (CRFM 2008). Landings estimates are from ICCAT Task I. In Grenada, the oceanic pelagic fishery has been the fastest growing fishery for the past 15 years and accounts for 71% of total annual fish catch. Species caught include yellowfin tuna, billfishes, and dolphin fish, with yellowfin tuna, which is mainly targeted for export, comprising 28% of total annual fish catch (FAO Fishery Country Profile). Over 65% of St. Lucia's annual fish landings comprise offshore migratory pelagics such as dolphinfish, wahoo, and tuna and tuna-like species, captured mainly between December and June each year.

With the exception of Venezuela, the Central-South American large pelagic fisheries can be considered modest and are underexploited, especially in the Central American countries. The Central American countries capture mainly dolphinfish, swordfish, sailfishes, marlin, jacks, and sharks in the Caribbean Sea, and dolphinfish and tunas in the Pacific Ocean. The coastal communities in this sub-region have limited access to these

[13] Anguilla, Antigua and Barbuda, Barbados, Bahamas, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, St.Kitts and Nevis, Suriname, St. Vincent and Grenadines, St. Lucia, Trinidad and Tobago, Turks and Caicos, UK Virgin islands

resources due to a lack of appropriate fishing and navigation equipment, illiteracy, poverty, and lack of government attention to these communities. In contrast to the Insular Caribbean countries that are more dependent on the large pelagic species for consumption and trade, the Central-South American continental countries target mainly demersal or small coastal pelagic species. Recent strategies to exploit the large pelagic resources as well as the technical support from extra-regional countries may promote the exploitation of these species, not only as a food source, but also for sport fishing, which is increasing in the region.

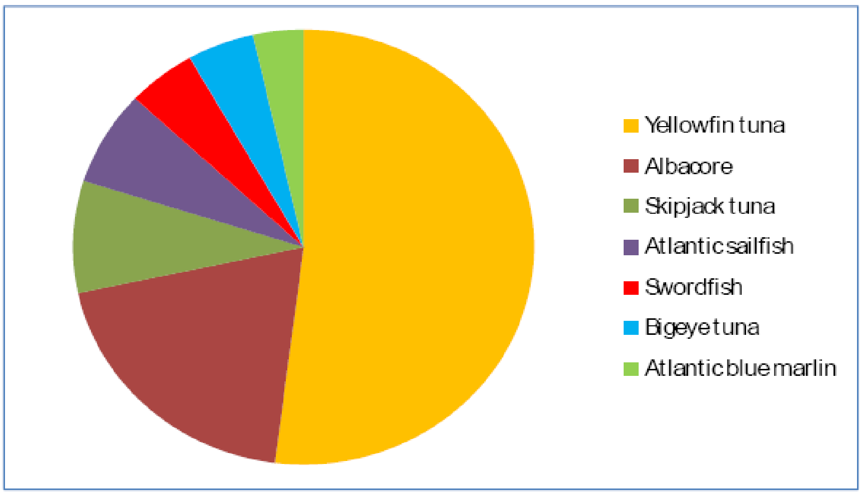


Figure 31. **Species regularly assessed by ICCAT landed by CRFM countries with the highest reported landings for the period 1990-2006**.

In the ICCAT database, catches of tunas in the tropical Western Atlantic in 2009 were dominated by yellowfin tuna, with Venezuela having the highest catch of this species (1,363 tonnes from purse seines and 929 tonnes from baitboats), followed by Grenada (630 tonnes from longlines) and Trinidad and Tobago (629 tonnes from longlines). The longliners also catch other large pelagics such as shark and billfish, often as bycatch. In the ICCAT database, the highest catches of blue marlin in 2008 were taken by Martinique (463 tonnes), followed by Guadeloupe (289 tonnes), St. Lucia (70 tonnes) and Grenada (54 tonnes). Between 1991 – 1999, in catches by the Venezuelan longline fleet, the billfish bycatch was 9.8% of the total catch, in which white marlin (*Tetrapturus albidus*) comprised 4%, blue marlin (*Makaira nigricans*) 2.4%, and sharks 3% (Arocha et al 2001). A number of large coastal pelagic species are also important components of longline bycatches.

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Table 17. ICCAT Task I reported catch (tonnes) for all CRFM countries for the period 1990-2006

Common name	Scientific name	Reported catch
Serra Spanish mackerel	*Scomberomorus brasiliensis*	40,432
Yellowfin tuna	*Thunnus albacares*	32,055
Dogfish sharks, etc. nei	Squaliformes	21,176
Tunas nei	Thunnini	15,664
King mackerel	*Scomberomorus cavalla*	14,089
Albacore	*Thunnus alalunga*	12,091
Wahoo	*Acanthocybium solandri*	7,282
Blackfin tuna	*Thunnus atlanticus*	6,153
Various sharks nei	Selachimorpha (Pleurotremata)	5,223
Skipjack tuna	*Katsuwonus pelamis*	5,130
Atlantic sailfish	*Istiophorus albicans*	4,345
Swordfish	*Xiphias gladius*	2,979
Atlantic bonito	*Sarda sarda*	2,906
Bigeye tuna	*Thunnus obesus*	2,889
Atlantic blue marlin	*Makaira nigricans*	2,162
Frigate tuna	*Auxis thazard*	1,565

Stock assessments of large pelagic resources have shown that some of these species are already being fished at or above MSY levels (discussed below). In assessments in 2006, some species were found to be in good condition, such as North Atlantic swordfish and South Atlantic Swordfish. The results of some of these assessments are often inconclusive or uncertain because of data weaknesses. A number of species are assessed and /or managed by ICCAT and/ or national and regional fisheries management bodies (e.g. USA, CRFM, WECAFC).

- ***Pelagic sharks***

Pelagic sharks are caught in the Caribbean (as well as Atlantic and Gulf of Mexico) with a variety of gears, including longlines, gillnets, handlines, rod and reel, trawls, trolls and harpoons. However, they are mostly caught as bycatch in pelagic longline fisheries targeting swordfish and tunas. The blue shark is one the most frequent species in the shark bycatches from Venezuelan tuna and swordfish fisheries. Another shark species commonly caught as bycatch is *Carcharhinus falciformis.* Although in the Caribbean sharks are often considered as bycatch, they are not usually discarded. In Colombia, for instance, shark bycatch are fully utilized. Sharks are in very high demand including on the international market where they fetch a very high price. The high demand for shark fins in the Asian market has been cause for concern, as this has promoted intense fishing pressure for these resources. Because of their life history strategy (low reproductive rate and live-bearers), sharks are very vulnerable to overfishing and a number of species are already threatened. The lack of data on sharks in the CLME region is a major constraint to their management.

- ***Marine mammals***

With the exception of the humpback whale fishery in St. Vincent and the Grenadines, directed fisheries in the Wider Caribbean usually target small or medium-sized cetacean species, and occasionally Bryde's whales. Whaling has traditionally been carried out by St. Vincent and the Grenadines and St. Lucia, with the primary target species being blackfish (pilot whale) *Globicephala macrorhynchus*. Other species of whale are taken by St Vincent, including false killer whale *Pseudorca crassidens*, small sperm whales *Physeter catodon*, pygmy killer whale *Feresa attenuata* and the dwarf sperm whale *Kogia simus*. National progress reports from some eastern Caribbean countries indicated that bottlenose dolphins (*Tursiops trancatus*), spotted dolphins (*Stenella frontalis*), spinner dolphins (*S. longirostris*), striped dolphins (*S. coeruleoalba*), Fraser's dolphins (*Lagenodelphis hosei*) and common dolphins (*Delphinus delphis*) have been harvested. Average annual catch of marine mammals in the LAPE area between 2001 and 2005 was 5.95 tonnes of killer whales (*Orcinus orca*, *Pseudorca crassidens* and *Feresa attenuate*) and 16.77 tonnes of shallow-diving small cetaceans (Mohammed et al 2007).

In the Eastern Caribbean, although directed takes of marine mammals are often considered sustainable, many of the species taken are collectively referred to as "blackfish" (e.g. pilot whales, false and pygmy killer whales, melon-headed whales, pygmy and dwarf sperm whales). There has been limited evaluation of the status of this fishery due to insufficient data.

Large coastal pelagics

Large coastal pelagic resources of commercial importance in the CLME include the following species:

- ✓ Dolphinfish (*Coryphaena hippurus*)
- ✓ Blackfin tuna (*Thunnus atlanticus*)
- ✓ Bullet tuna (*Auxis rochei*)

- ✓ Frigate tuna (*A. thazard*)
- ✓ Atlantic bonito (*Sarda sarda*)
- ✓ Serra Spanish mackerel (*Scomberomorus brasiliensis*)
- ✓ Cero mackerel (*S. regalis*)
- ✓ Atlantic Spanish mackerel (*S. maculatus*)
- ✓ King mackerel (*S. cavalla*)
- ✓ Little tunny (*Euthynnus alletteratus*)
- ✓ Wahoo (*Acanthocybium solandri*)

The large coastal pelagics are considered as small tunas by ICCAT. Five species account for about 88% of the total reported catch by weight in the Atlantic region (ICCAT): Atlantic bonito *(Sarda sarda)*, frigate tuna *(Auxis thazard)*, which may include some catches of bullet tuna *(Auxis rochei)*, little tunny *(Euthynnus alletteratus)*, king mackerel *(Scomberomorus cavalla)*, and Atlantic Spanish mackerel *(Scomberomorus maculatus)*.

Most of the large coastal pelagic species have been conventionally fished throughout the region and have a high socio-economic relevance for most of the countries and for many local communities as a main source of food and livelihoods. These resources are largely confined to the WECAFC area and are fished on island and continental shelves using mainly handlines (including with live bait), long lines, beach seine and gill nets. Large coastal pelagic species are exploited mainly by coastal artisanal and commercial fisheries, but some of them such as dolphinfish and wahoo are also important in recreational fishing. The increasing importance of fish aggregating devices (FAD) in the eastern Caribbean and in other areas has improved the efficiency of artisanal fisheries in catching these resources. Substantial catches are made as target species and as bycatch by purse seine, handlines, longlines and small scale gillnets. The large industrial fleets often discard these bycatches at sea or sell them on local markets mixed with other bycatch species.

Recreational fishing (by individuals with their own boats or by charter vessels) for large pelagic species can be a significant component of the harvest sub-sector in many places. These fisheries can have a significant impact on pelagic resources and can be a source of potential conflicts with the commercial sector. Recreational fisheries for large pelagics therefore need to be taken into account in the assessment of and the development of management strategies for these resources. Improved data and information on recreational fisheries are also needed. Organized fishing tournaments are held in many countries but these do not appear to be coordinated. There are nine sport fishing associations in CARICOM that could provide an opportunity for coordinated activity at the local and regional level. Among the major species targeted are billfish, wahoo, and king mackerel. Mahon (2004) made a rough valuation of recreational fisheries for charter vessels based on about 85 charter boats in CARICOM countries. The total annual revenue for all boats was estimated at about US$6.6 million, equivalent to about 9% of the value of commercial fisheries. This does not include earnings from the sale of fish caught.

Knowledge on the biology and fishery of large coastal pelagics is very fragmented in several areas. Furthermore, the quality of the knowledge is very different according to the species concerned. This is due in large part because many of these species are often perceived to have little economic importance compared to other tuna and tuna-like species, and owing to the difficulties in conducting sampling of the landings from artisanal fisheries, which constitute a high proportion of the fisheries exploiting small tuna resources. Of these resources, the largest landings come from serra Spanish mackerel, dolphinfish, king mackerel and wahoo (Figure 32, Table 17) (CRFM 2008). Landing estimates are from ICCAT Task I but dolphinfish landings are estimates from FAO.

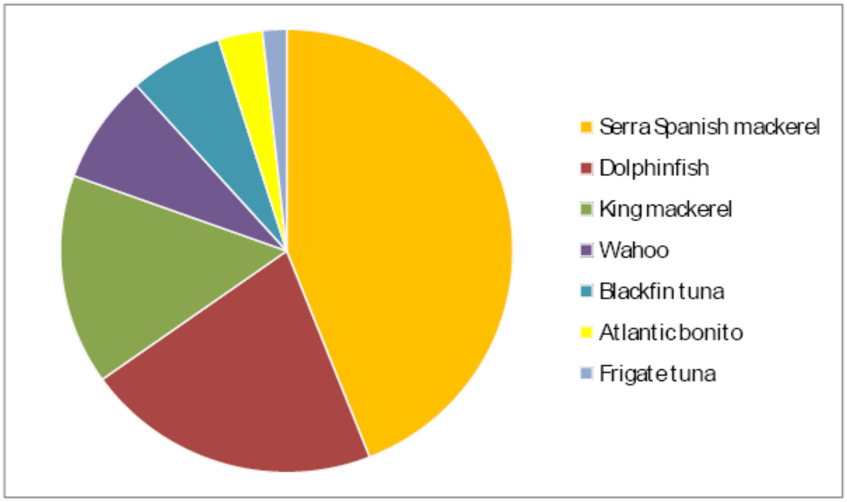


Figure 32. Species landed by CRFM countries with the highest reported landings that are not regularly assessed by ICCAT for the period 1990-2006

For the CLME project, the following species are of particular interest, with case studies being conducted: flyingfish, dolphinfish, wahoo, mackerels (cero and king mackerel), blackfin tuna and bullet tuna. Flyingfish is included as this is a commercially important, shared resource in the Eastern Caribbean, and has close ecological and fisheries interactions with large pelagics such as dolphinfish and wahoo. A brief description of the fisheries for these species is given below.

- ***Flyingfish***

The following account of the flyingfish fishery is based mainly on Mohammed et al (2008) and Fanning and Oxenford (in press). The fisheries for flyingfish are concentrated in the southern part of the Lesser Antilles, with significant small-scale commercial fisheries in Barbados, Grenada, Martinique, St. Lucia, and Tobago (Oxenford et al 2007). In this sub-region, the fourwing flyingfish is believed to contribute to 95% of the catches (Mohammed et al 2008). In Barbados, flyingfish dominate the local industry and has great economic and cultural significance[14]. Flyingfishes account for almost two-thirds of total landings in this

[14] Barbados has been dubbed “the Land of the Flyingfish”.

country, with the four-winged flyingfish comprising more than 90% of the flyingfish catch (FAO Fishery Country Profile for Barbados). During the period 1994 to 2003, annual estimated catches of flyingfish in Barbados ranged from 1,500 to 2,600 tonnes. Recorded flyingfish landings, however, have dropped significantly in Barbados although the fleet size has increased and the catch per trip has remained stable (Staskiewicz et al 2008). In 2006, about 99 tonnes of flyingfish were landed in this country (Sea Around Us Project 2010). In Barbados, the flyingfish fishery is a high value-added fishery, especially through sales in the tourism sector (Mahon et al 2007). Almost the entire catch, excluding that small amount used for bait, is sold for human consumption. This is changing, however. There are also important flyingfish fisheries in Tobago, Martinique, and St. Lucia for human consumption.

The fishery for flyingfishes takes advantage of their spawning behaviour to aggregate in large schools around floating objects on which they deposit their eggs. The major gears are surface floating gillnets, handheld dipnets, and 'screelers', which are made of floating debris, usually palm fronds or sugar cane leaves and are attached to the gear (Fanning and Oxenford, in press).

The directed flyingfish fishery is part of a multi-species, multi-gear pelagic fishery. While travelling to and from port and while the gillnets are soaking, fishers use either trolled or stationary hook and line gear (baited with flyingfish) to catch regional large pelagic species, primarily dolphinfish, but also wahoo and ocean triggerfish (*Canthidermis* spp.). These two activities are largely inseparable as neither is likely to be economically viable alone, and the major flyingfish catch comes from this troll/gillnet sector (Fanning and Oxenford, in press).

A fishery re-directed at flyingfish for bait has emerged with the development and expansion of longlining in the region, particularly in Grenada. Since flyingfish is highly seasonal, small coastal pelagic species taken with local beach seines are used as bait when flyingfish is seasonally unavailable. The catch statistics for flyingfish for the region are incomplete, and the amount used for bait fishery is not recorded in any of the countries involved. As a result, there is no clear picture of actual flyingfish catches in the region.

Throughout their range, the various species of flyingfishes are an important prey group for a variety of large pelagic predators. For example, flyingfishes make up more than 15% of the diet of bigeye tuna, dolphinfish, and large mesopelagic predators and more than 5% of the diet of billfishes, blackfin tuna, and squid (Heileman et al 2008 and references therein). In the eastern Caribbean, various flyingfish species were estimated to make up more than 40% of the total diet of dolphinfish (Oxenford and Hunte 1999).

There is a very close migratory timing of fourwing flyingfish and dolphinfish. These two species are tightly linked through trophic, technical, and economic interactions (Fanning and Oxenford, in press). The strong trophic dependence of dolphinfishes on flyingfishes was investigated using an ecological model (Ecopath with Ecosim) of the Lesser Antilles pelagic ecosystem (Mohammed et al 2008). The model results are indicative of the importance, strength, and direction of ecological interactions involving flyingfishes and illustrate technical and economic interactions between flyingfishes and other fisheries The results suggest that increasing fishing effort in the gillnet/troll fishery, which targets four wing flyingfish, dolphinfish and wahoo, will almost certainly result in decreased biomass of dolphinfishes.

The WECAFC *Ad Hoc* Flyingfish Working Group of the Eastern Caribbean carried out an assessment of the Eastern Caribbean flyingfish stock. An overview of the assessment presented in CRFM (2009) suggested that the stock was not currently overfished. Catch rates have remained stable overall in the time series as catches have increased. The potential yield appeared to be greater than the total catches taken during the fishery's history, since the stock area and stock size were estimated to be relatively large. In consequence, unless a significant increase in catches occurred, no immediate management action was required. The maximum recorded catch so far has been 4,700 tonnes. In order to avoid overfishing, the establishment of a 5,000 tonnes catch trigger was suggested by the WECAFC Working Group. The assessment indicated that any fisheries development exceeding 5,000 tonnes would have unpredictable consequences.

The flyingfish provides a good example of a species for which EAF management is highly appropriate (Fanning and Oxenford, in press). Tagging studies indicated considerable movements of the fourwing flyingfish between the countries in the Eastern Caribbean, which suggest that the minimum appropriate management unit for this species should be the combined EEZs of these countries (Oxenford et al. 1993). The regional distribution of these species will require multilateral management by the states and territories involved.

- ***Dolphinfish***

The dolphinfish is a highly migratory pelagic species that is targeted by both commercial and recreational fishers throughout its geographic range. Dolphinfish is caught during the first half of the year with a variety of commercial hook and line gear (handlines, vertical and surface longlines) deployed from motorized fishing vessel. As dolphinfish is a major predator of flyingfish the two species are often taken on the same fishing trips. This species is known to aggregate around floating objects and are often taken around FADs. It is also caught incidentally by tuna longline vessels.

Within the Eastern Caribbean, dolphinfish constitutes a very substantial portion of total offshore pelagic catches, with Barbados conventionally having the largest total dolphinfish landings in the sub-region. However, statistics in the Sea Around Us database showed that the highest reported landings in 2006 were in Guadeloupe (700 mt), followed by St. Lucia (382 tonnes), Martinique (125 tonnes) and Barbados (19 tonnes).

An assessment of the dolphinfish stock in eastern Caribbean waters suggested that fishing mortality is much greater than that required for MSY, and as a result, catches from the stock are much lower than MSY (Parker et al 2000). These results were highly uncertain, however, and the apparent high fishing mortality estimated may reflect a migration of fish out of the eastern Caribbean (Die 2004). CRFM (2006), in a more recent assessment, concluded that dolphinfish catch rates (catch per trip) have remained fairly level over 1995 -2004, fluctuating between 50 – 62 kg per trip (Figure 33). Given the lack of any concrete signs of a decline in catch rates over this period, it was concluded that catches of dolphinfish are sustainable at current levels of harvest. However, the weakness in data was emphasized. For the purpose of assessing a regionally shared stock, the dataset used for the analyses was very limited both in terms of the number of fishing countries represented and the number of years for which records was provided (CRFM 2006). Given the importance of this species to most eastern Caribbean countries it is important that greater efforts be made to collect and provide the data needed for stock analyses in the future.

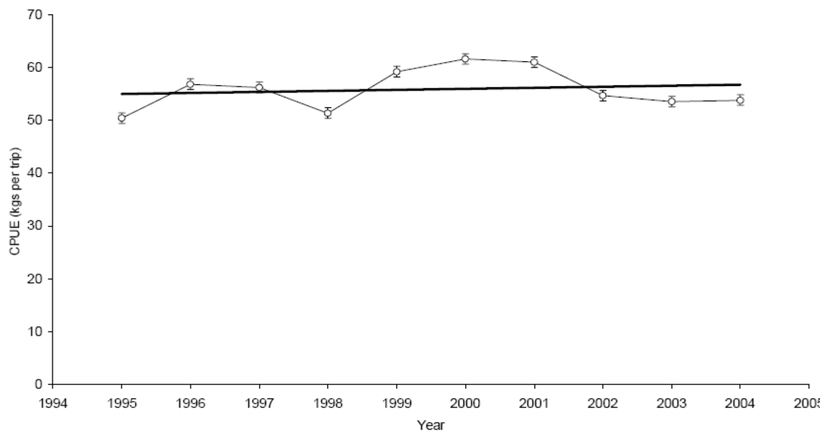


Figure 33. **Trends in dolphinfish catch rates (catch per trip)**

Castro et al (2007) gave a description of the fishery for large pelagic resources in the Seaflower MPA in San Andres archipelago, Colombia, including trends in CPUE for the period 2004 -2006. Dolphinfish landings peaked from February–May and were 73 tonnes in 2004, 39 tonnes in 2005, and 25 tonnes in 2006. The large pelagic fish resources, including dolphinfish, around the southern section of the Seaflower MPA experienced slight but progressive reductions in mean CPUE during the 3 years. This was attributed to the redirection of fishing from reef to pelagic species when the former were fished out, and an enormous increase in the number of fishers as well as the catching of juveniles (about 4% of dolphinfish caught were juveniles).

The greatest regulation of dolphinfish in the western Atlantic is the US Fishery Management Plan for Dolphin and Wahoo in the Atlantic Region, which sets limits on catches of dolphin and wahoo for commercial and recreational fishers in federal waters along the entire Atlantic coast. There are no active management regulations specifically for dolphinfish in any of the eastern Caribbean countries, although the need to manage this species at the regional level appears to be generally well accepted (CRFM 2006). Indeed, the formation of a multinational management body for dolphinfish featured prominently in a recent FAO sponsored study on management options for the large pelagic fisheries of the eastern Caribbean. However, these regional management arrangements are yet to be finalized (CRFM 2006).

- ***Wahoo***

Wahoo is particularly important in the Caribbean in both commercial and recreational fisheries. In the ICCAT database, in 2009 St. Lucia contributed the highest catch of wahoo (195 tonnes), followed by St. Vincent and the Grenadines (31 tonnes) and Barbados (14 tonnes). St. Lucia contributes the largest proportion of wahoo captured among the CRFM countries that currently report wahoo catches to FAO (48% based on mean annual catches reported to FAO for the period 1990-2004).

There is no strong indication that the eastern Caribbean population is a separate stock from the stock present in the rest of the Caribbean. George et al (2000) assessed the wahoo stock in eastern Caribbean waters using a combination of length-based models. Their results suggest that fishing mortality is much greater than that required for MSY and that, as a result, catches from the stock are much lower than MSY. These results are highly uncertain and dependent on growth parameters not yet well estimated (George et al 2000). They may also be biased, because there is no strong indication that the eastern Caribbean population is a separate stock from the stock present in the rest of the Caribbean. Thus, the apparent high mortality estimated may reflect a migration of fish out of the eastern Caribbean (Die 2004).

An update of the stock assessment for wahoo utilizing landings datasets for the Barbados moses and dayboat fleets and the St. Lucia pirogue fleet for the period 1996 - 2006 showed no declining trend in the catch rates over this period, as shown in Figure 34 (CRFM 2007). Based on this observation it was inferred that the local abundance of the stock was sustainable at these levels of harvest at least in the short term. It was noted, however, that these assessments cannot be considered extensive enough to predict the long-term sustainability of the fishery at current or increased levels of exploitation. Therefore, a precautionary approach should be adopted in managing and further developing this fishery until the stock dynamics are better understood. Given the number of nations that are likely to be fishing the wahoo stock within the WECAFC area and the possible interests of some fishing nations to expand their pelagic fisheries, management of the wahoo fishery should be based on collaborative arrangements between the CRFM and major non-CRFM fishing nations in the region (CRFM 2007).

On the Seaflower MPA in San Andres archipelago, Colombia, during the period 2004 - 2006, the second most abundant species (after blackfin tuna) was wahoo, which comprised 28%, 19% and 13% of the annual large pelagic landings, respectively (Castro et al 2007). During this period, about 32.8 tonnes of wahoo were caught, with a primary peak in November–January and secondary peaks in April and July–August. The large pelagic species, including wahoo, experienced progressive reductions in mean CPUE during the 3 years. This was attributed to the redirection of fishing from reef to pelagic species when the former were fished out, and an enormous increase in the number of fishers as well as the catching of juveniles (about 18% of wahoo caught were juveniles).

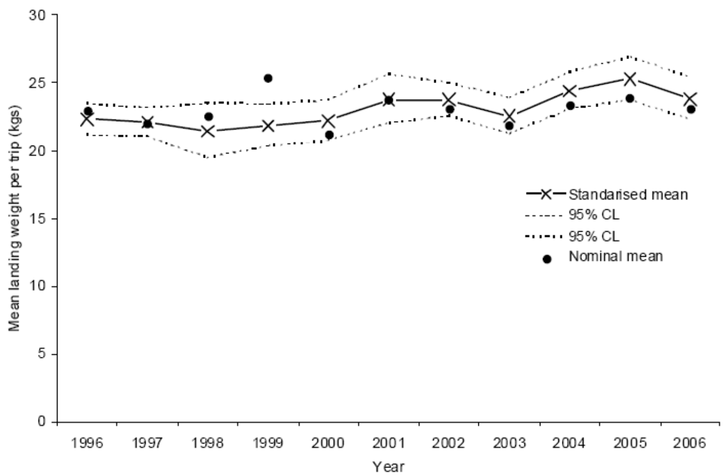


Figure 34. Standardized catch rates for Barbados moses and dayboats and St. Lucia pirogues (1996 to 2007)

- ***Mackerels***

Mackerels, particularly king mackerel and serra Spanish mackerels, are commercially important in a number of CLME countries and territories. They are considered part of a multi-species complex of coastal pelagic species taken by a combination of gears and fleets. The fishery includes a number of shark species, among others. Landings in CRFM countries between 1990 – 2006 were dominated by the Spanish mackerel (40,432 tonnes), followed by king mackerel with 14,089 tonnes (CRFM 2008) (Table 17). In the ICCAT database, landings in 2009 of king mackerel were highest for Trinidad and Tobago (318 tonnes). Annual reported landings of king mackerel between 1950 and 2006 from the Sea Around Us Project show fluctuating catches, with the highest in 1974 of nearly 7,000 tonnes. The general trend, however, is increasing landings of this resource (Figure 34). In the Sea Around Us database, in 2006 (the latest year for which data are available), the reported landings of king mackerel by Trinidad and Tobago were 863 tonnes, Puerto Rico 539 tonnes and Dominican Republic 180 tonnes. According to the ICCAT database, landings of serra Spanish mackerel in 2009 were highest in Trinidad and Tobago (2,514 tonnes). These two species are also known to be of commercial importance in other countries such as Venezuela.

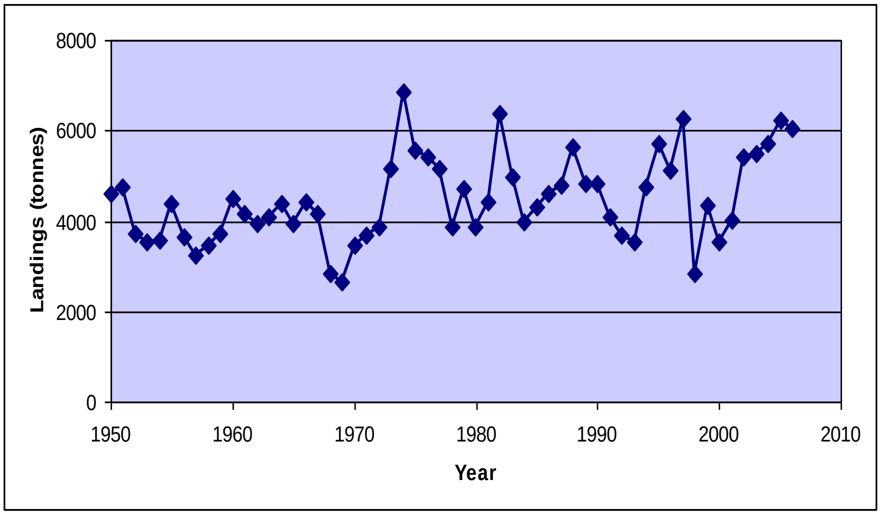


Figure 35. Annual reported landings of king mackerel in the CLME region

A review of the fishery for king mackerel in Trinidad is given by CRFM (2006). King mackerel is caught commercially by hook and line gears (including with live bait) as well as gillnets and seines. In Trinidad, the species is targeted by the pelagic hook and line components of the semi-industrial multi-gear fleet and the inshore artisanal multi-gear fleet. It is also a primary by-catch of the gillnet component of the inshore artisanal fleet that targets Serra Spanish mackerel. Stock assessment of king mackerel in Trinidad and Tobago has been conducted (CRFM 2006, 2007). Despite uncertainties in the data and models used, the kingfish fishery in Trinidad and Tobago was found to be at risk of recruitment failure and there was cause for concern, although the stock assessment remains inconclusive. The uncertainty in stock status forces management to take a precautionary approach and it was recommended that the current levels of fishing effort should not be increased. Similarly, the fishing effort for king mackerel in Colombia has been reported to be above that required for a sustainable catch (Barreto and Borda 2008). Size and gear restrictions for king mackerel are in place in Trinidad and Tobago though they are not enforced. King mackerel in waters off Puerto Rico and the US Virgin Islands are managed by the US.

Information on cero mackerel (*S. regalis*) is limited in the CLME region. In the Caribbean, fisheries for cero mackerel exist in the Insular Caribbean (Bahamas, Cuba, Dominican Republic, Jamaica) as well as in Venezuela. In US waters, there is only a small directed fishery off Florida for this species, which are also are caught incidentally in king kackerel fisheries in the South Atlantic and Gulf of Mexico. The National Marine Fisheries Service Caribbean Fishery Management Council does not manage these cero mackerel fisheries. In the ICCAT database, landings of this species in 2008 and 2009 are recorded from St. Lucia (11 tonnes total for the two years). Between 1995 and 1998, over 1,000 tonnes of this species were taken by Martinique.

- ***Blackfin tuna***

The landings of blackfin tuna, a highly migratory species, differ markedly among countries within the known geographic range of the species. In the Western Atlantic, the highest quantities are landed by Venezuelan fleets. The southeastern coast of Cuba is known to be one of the richest fishing grounds for the species (CRFM 2008). Among the Eastern Caribbean countries, by far the largest recorded quantities of blackfin tuna are traditionally landed in Martinique and Guadeloupe followed by Grenada, with Grenada taking the most blackfin tuna amongst the CRFM member countries. In the ICCAT database the highest landings for this species in the western Tropical Atlantic in 2008 were taken by Grenada (290 tonnes) and St. Lucia (179 tonnes), with the USA taking 30 tonnes.

The species is often taken along with skipjack tunas (*Katsuwonus pelamis*) with which it often forms mixed schools. The species is caught by a number of gears. In Cuba, blackfin tuna are mainly taken by live bait and jackpole. In Venezuela, in addition to baitboat fishing, blackfin tuna are taken on long lines and in purse seines. In the Eastern Caribbean this species is mainly taken by trolling over coastal shelf areas. It is also found around seamounts, drifting objects and moored-FADs, facilitating their capture by simple trolling gear in these deeper waters (Taquet et al. 2000). Blackfin tuna landed at Martinique are reportedly taken mainly by trolling around FADs or over seamounts. This species are also important for the sports fisheries of the Bahamas and Florida.

Castro et al (2007) gave a description of the fishery for blackfin tuna in the Seaflower MPA in San Andres archipelago, Colombia, including trends in CPUE for the period 2004 -2006. Blackfin tuna dominated the large pelagic landings during this period, with about 103 tonnes landed, accounting for 55% of the catch in 2004, 61% in 2005, and 78% in 2006. The large pelagic fish resources, including blackfin tuna, around the southern section of the Seaflower MPA experienced slight but progressive reductions in mean CPUE during the 3 years. This was attributed to the redirection of fishing from reef to pelagic species when the former were fished out, and an enormous increase in the number of fishers as well as the catching of juveniles (more than 70% of blackfin tuna caught were juveniles). The depletion phenomenon observed around San Andres Island may now be appearing at medium distance reefs and threaten more distant reefs. Unexpected results showed how higher proportions of juveniles are taken from offshore environment (up to 76% for blackfin tuna and skipjack tuna) than the coastal ones (18% for wahoo and 4% for dolphinfish).

These authors recognized that there is potential for the evaluation and subsequent recommendation for more appropriate management of these large pelagic stocks with the integration of existing initiatives and regional programmes, such as those of CARICOM, the International Commission for the Conservation of Atlantics Tunas (ICCAT) and the Western Central Atlantic Fisheries Commission (WECAF).

- ***Bullet tuna***

Auxis species is widespread in the western Atlantic with an uninterrupted distribution from the Rio de la Plata in Argentina to the northern US coast, including the entire Caribbean and the Gulf of Mexico. Information on the bullet tuna (*A. rochei*) in the CLME is very limited. Unknown quantities of bullet tuna are landing and recorded as frigate tuna (*A. thazard*) in the Atlantic (ICCAT 2006), where catches of *Auxis* species are usually not identified to species. Thus, in the total catch of frigate tuna, the proportion of each of these two species is not known. Frigate tuna is exploited mainly by artisanal fisheries using surface gears such as trolling lines, handlines, small-scale longlines, and a wide variety of nets, including gill or drift nets, ring nets, beach seines, otter trawls, and purse seines. In purse seine fisheries for yellowfin and skipjack tuna, *Auxis* species are taken incidentally as by-catch. In the Insular Caribbean, frigate tunas are mainly landed in Trinidad and Tobago. *Auxis thazard* is caught around FADs in Martinique and used as bait in drifting handlines that target large tuna and marlins (Reynal *et al*. 2006) but is also often landed and sold.

A number of countries/territories in the Western Atlantic report catches of frigate tuna to ICCAT. These include Venezuela, USA, Panama, and Netherland Antilles. In 2008 and 2009, the Venezuelan catches of *A. thazard* in the ICCAT database were 48 and 54 tonnes, respectively. Almost the entire Venezuelan and Atlantic catch is supposedly *A. rochei*. Reports from Panama, Netherland Antilles and part of the reports from Venezuela are from purse seiners, so some of these catches may have been made in the Eastern Central Atlantic.

4.2. Analysis of the current issues

This section provides a brief overview of the major issues in the pelagic ecosystem. These issues will be discussed in greater detail in subsequent sections. The pelagic ecosystem provides enormous social and economic benefits to the countries and people of the region, particularly the large pelagic fisheries resources that are truly transboundary and shared among the countries within as well as with countries outside the region. While the pelagic realm is often seen as a vast expanse of ocean with unlimited living resources, heavy and in many cases non-selective fishing, land and marine-based pollution, and climate change are leading to decline in these valuable resources and degradation of the pelagic habitat. This has implications, not only for the pelagic resources themselves, but also for the reef ecosystem owing to the high connectivity between these two systems (e.g. transport of pelagic eggs and larvae of reef organisms from spawning grounds to settlement and recruitment areas), and the entire CLME.

A major concern is the unsustainable exploitation of large pelagic fisheries resources. Their high economic value and demand globally drive intense fishing pressure for these resources throughout their range. As a consequence, a number of these stocks are already showing signs of overfishing and collapse. A number of CLME countries are members of ICCAT or have adopted regional and international management frameworks relevant to large pelagic fisheries (e.g. UN Law of the Sea Convention relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, CITES, FAO Code of Conduct for Responsible Fishing). Yet, because of poor implementation and enforcement at national and regional levels, among other factors, these resources continue to be unsustainably exploited. Furthermore, the lack of adequate data and information across the scale of the CLME is a major constraint to proper management of the region's transboundary resources. This is demonstrated in CRFM and ICCAT assessments, which are often inconclusive because of insufficient data from the countries that exploit these shared resources. There is urgent need for countries to collaborate and to share information that has been collected in a harmonized manner. Limited knowledge about the stock structure of some of these migratory resources is another source of uncertainty in the assessment and management of these resources.

The high incidence of bycatch in pelagic fisheries, particularly of endangered or threatened species with already small population sizes, is a leading conservation concern. Although bycatches occur in nearly every type of fishing gear, in a study of the USA east coast commercial fisheries, gillnets and longlines were found to have the highest bycatch of a number of threatened and endangered species (Zollett 2009). Regional estimates of bycatch from the CLME pelagic fisheries were not available, but records from Venezuela and Colombia are presented below.

The issue of Illegal, Unreported, and Unregulated (IUU) fishing is an enormous problem with respect to the pelagic resources as most countries do not have the capacity for surveillance and enforcement in their respective EEZs. IUU fishing contributes to overexploitation of fish stocks and is a hindrance to the recovery of fish populations and ecosystems. According to the FAO, IUU fishing is increasing in both intensity and scope and is continuing to undermine national and regional efforts to sustainably manage fisheries.

Related to IUU is another issue of concern – Flags of Convenience (FOC) –especially for vessels fishing on the high seas (Box 10). An analysis of information available from the Lloyd's Register of Ships between 1999 and 2005 on fishing vessels registered to the top 14 countries that operate open registries or 'Flags of Convenience' for large-scale fishing vessels was undertaken under the auspices of the World Wildlife Fund International and others (Gianni and Simpson 2005). Four CLME countries (Belize, Honduras, Panama, and St. Vincent and the Grenadines) have consistently topped the list of FOC countries with the largest number of large-scale fishing vessels (>24m) registered to fly their flag. These four countries alone have accounted for 75% or more of the fishing vessels flying the flag of the FOC countries listed between the years 1999-2005. Using Lloyd's data, Taiwan, Honduras, Panama, Spain, and Belize are the top five countries where companies that own or operate fishing vessels flagged to one of the top 14 FOC fishing countries are based. An agreement is in place to address IUU fishing – the UN FAO International Plan of Action to Prevent, Deter and Eliminate IUU fishing. It has been recommended that the single most effective means to implement the agreement, which highlights the FOC role in perpetuating IUU Fishing, is to eliminate the FOC system.

Box 10. Flags of Convenience promote IUU fishing

As of July 2005, over 1,000 large-scale fishing vessels continue to fly Flags of Convenience (FOCs), in spite of significant global and regional efforts over recent years to combat IUU fishing on the High Seas. This activity, primarily by FOC fishing Fleets, contributes to unsustainable fishing and failure to effectively manage these fisheries. The FOC system provides cover to a truly globalized fishing fleet engaged in what is largely illegal or unregulated fishing activity on the high seas, to the detriment of international efforts to conserve fisheries and protect other species in the marine environment. Many, if not most, of these vessels deliberately register with FOC countries to evade conservation and management regulations for high seas fisheries. While not all of these vessels may be involved in IUU fishing, the large number of FOC fishing vessels severely impairs the ability of responsible countries and regional fisheries management organizations to monitor, control and manage fisheries on the high seas and eliminate IUU fishing. The irony is that while the FOC fishing business on the high seas may be worth a billion dollars or more per year, the top four FOC fishing countries only take in a few million dollars per year in fishing vessel registration fees.

(Gianni and Simpson 2005)

Climate change has become a major pervasive force affecting the region's marine habitats. This phenomenon (including increasing sea surface temperatures) could affect ocean circulation patterns and the survival and distribution of pelagic living resources, as described below.

As nearshore habitats and resources are degraded and depleted, exploitation is shifting towards offshore areas. In the absence of appropriate management interventions to recover inshore habitats and living marine resources and protect those in offshore areas, these negative trends are likely to continue. These pressures are expected to increase with growing population and demand for fisheries resources. Greater amount of waste production and disposal in the marine environment would also be expected if measures are not implemented to address these issues.

The priority issues identified in the preliminary TDAs were: unsustainable exploitation of fish and other living marine resources, habitat degradation and community modification, and pollution. More recent analyses have reinforced these findings and confirmed the continuing importance of these three issues in the region (e.g. CARSEA 2007, Brown et al 2007, Heileman and Mahon 2008). Climate change is also expected to have severe negative impacts on the pelagic realm and its living resources.

4.2.1. Unsustainable exploitation of pelagic living resources

Fisheries overexploitation has been assessed as severe in the Caribbean Sea (UNEP 2004a, 2004b, 2006). Unsustainable exploitation of pelagic fisheries resources is of major transboundary significance owing to the shared and/or migratory nature of these species. Declines in catch per unit effort (CPUE), reduction in the size of fish caught, and changes in species composition are all indications of unsustainable exploitation in the region. Not only has unsustainable exploitation affected targeted stocks, but it has also contributed to declines in abundance of other animals such as sharks and marine mammals that are taken as bycatch.

The major environmental impacts of unsustainable exploitation of pelagic fish stocks include:

a. Reduced abundance of fish stocks (as evident in declines in total catch and catch per unit effort (CPUE) and collapsed stocks);

b. Changes in trophic structure of fish populations, with a trend towards small, low trophic level species;

c. Threats to biodiversity

<u>Reduced abundance of stocks</u>

The annual reported landings of medium pelagic species in the Sea Around Us Project database showed a general increasing trend (with some fluctuations) until 1998, followed by a marked decline until 2001.

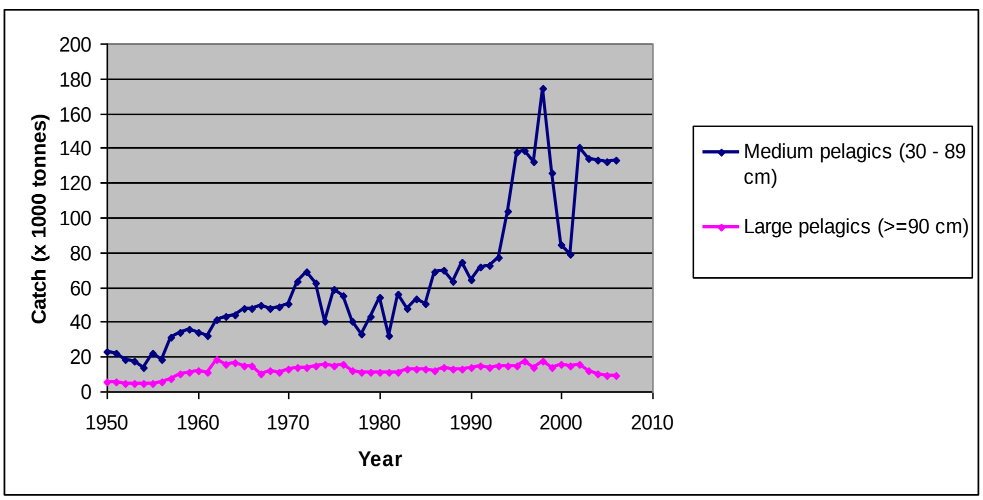


Figure 36. Trends in annual catches of large and medium pelagic fish in the CLME from 1950 – 2006

The landings then increased in 2002, and then declined slightly in the following four years (Figure 36). The annual landings of large pelagics were fairly stable until 2002, following which they declined slightly. This trend of overall stable landings of large pelagics (despite reports of overexploited and collapsed stocks – see stock status plots below) could be due to increasing effort and expansion of the area being exploited. In the Caribbean, increasing fisheries yields appeared to be driven principally by heavy exploitation (Sherman et al 2009).

Some of the HMS & SS are already considered to be overfished throughout the Atlantic Ocean (Die 2004). These include the Atlantic swordfish (ICCAT 2001a) and Atlantic blue marlin and white marlin (ICCAT 2001b). The abundance of Western Atlantic sailfish fell dramatically in the 1960s and has not increased much since. Current catches seem sustainable (ICCAT 2001b), but it is not known how far the current levels are from MSY. In spite of fisheries regulations, the oceanic fishing industry continues to decline, with almost 70% of the stocks fully exploited or overfished. More recent assessments by ICCAT found that a number of these species are still overexploited, with catches continuing to decline. Among these are blue and white marlin, sailfish and yellowfin tuna. For instance, the ICCAT Standing Committee on Research and Statistics (SCRS) inferred that effective effort for yellowfin tuna may have been either slightly below or above (up to 46%) the MSY level, depending on the assumptions. A stock assessment of northern albacore conducted in 2007 showed that the stock was overfished. Some local exploitation of skipjack tuna was reported. For bigeye tuna as well as blue and white marlin, both the biomass and fishing mortality rates were estimated to be at unfavourable levels. In the Eastern Caribbean, the wahoo and dolphinfish were considered to be overexploited and current fishing mortality not sustainable (CFRAMP 2001).

Faced with the overexploited state of inshore fisheries and the increasing need for food security, many governments, especially in the Eastern Caribbean have promoted development of the offshore fishery for large pelagic species such as tuna through the provision of loans and other incentives. Calculation of CPUE trends in four of the Windward Islands (Mohammed 2003) show that increases in offshore catches between 1980 and 1999 (36% to 143%) were far outweighed by the corresponding increases in fishing effort to produce such catches (339% to 598%). CPUE declined substantially in the offshore fisheries of each of the four countries (by a range of between 52% and 69%), despite increasing fishing effort.

Meyers and Worm (2003) estimated that the current global large predatory fish biomass is only about 10% of pre-industrial levels. For oceanic ecosystems, they used Japanese pelagic longlining data, which represented the complete catch-rate data for oceanic pelagic species (tuna, billfishes, and swordfish). They concluded that earlier declines of large predators in coastal regions (Jackson et al 2001) have extended throughout the global ocean, with potentially serious consequences for marine ecosystems (Figure 37). These trends are also evident in the CLME, as discussed below.

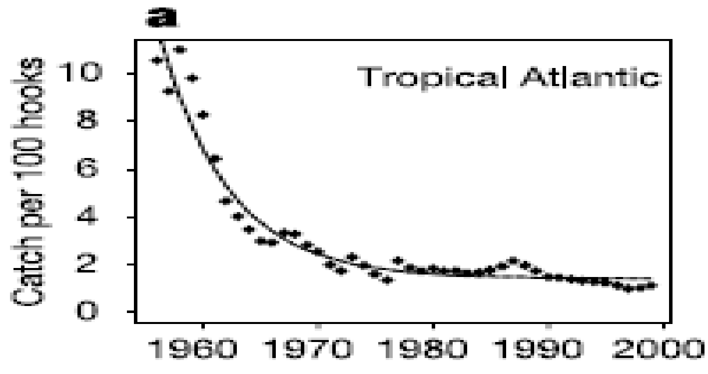


Figure 37. Time trends of pelagic biomass in the tropical Atlantic from the beginning of industrialized fishing

Annual trends (from 1950 to 2006) in the overall status of medium and large pelagic fish stocks in the CLME are represented by the Stock Status Plots[15] (Figure 38). These plots assess the status of stocks by number of stocks (top) and by catch biomass (3-year running average values; bottom) since 1950 (Sea Around s Project 2011). Stock-status categories are defined using the following criteria (all referring to the maximum catch [peak catch] or post-peak minimum in each series): *Developing* (catches ≤ 50% of peak and year is pre-peak, or year of peak is final year of the time series); *Exploited* (catches ≥ 50% of peak catches); *Over-exploited* (catches between 50% and 10% of peak and year is post-peak***);*** *Collapsed* (catches < 10% of peak and year is post-peak); and *Recovering* (catches between 10% and 50% of peak and year is after post-peak minimum). Note that (n), the number of 'stocks' is defined as a time series of a given species, genus or family (higher and pooled groups have been excluded) for which the first and last reported landings are at least 10 years apart, for which there are at least 5 years of consecutive catches and for which the catch in a given area is at least 1,000 tonnes.

As can be seen in the top panel of Figure 38, for those stocks included in the analysis, the number of overexploited and collapsed stocks increased markedly from the late 1970s. While the former stabilized and even declined in recent years, the proportion of collapsed stocks continued to steadily increase to almost 40% in 2006. In 2006, about 60% of the pelagic stocks were overexploited and collapsed and about 10% rebuilding. In 2006 about 10% of the catch came from overexploited stocks (decreasing from nearly 70% in 2000 - 2002), with negligible catches from collapsed, developing or rebuilding stocks (Figure 38, bottom). As for reef fish stocks, these trends confirm the widespread reports of overexploited and collapsed stocks in the CLME, and are consistent with the unregulated expansion of fishing in previous decades. The results of these analyses are very useful in providing a holistic picture of the status of the pelagic resources and conveying strong messages to policy makers about the need to reverse or prevent further declines.

[15] These analyses and plots for pelagic stocks were provided specifically for the CLME project by the University of British Colombia Sea Around Us project (the analyses are usually carried out for combined stocks of reef and pelagic species)

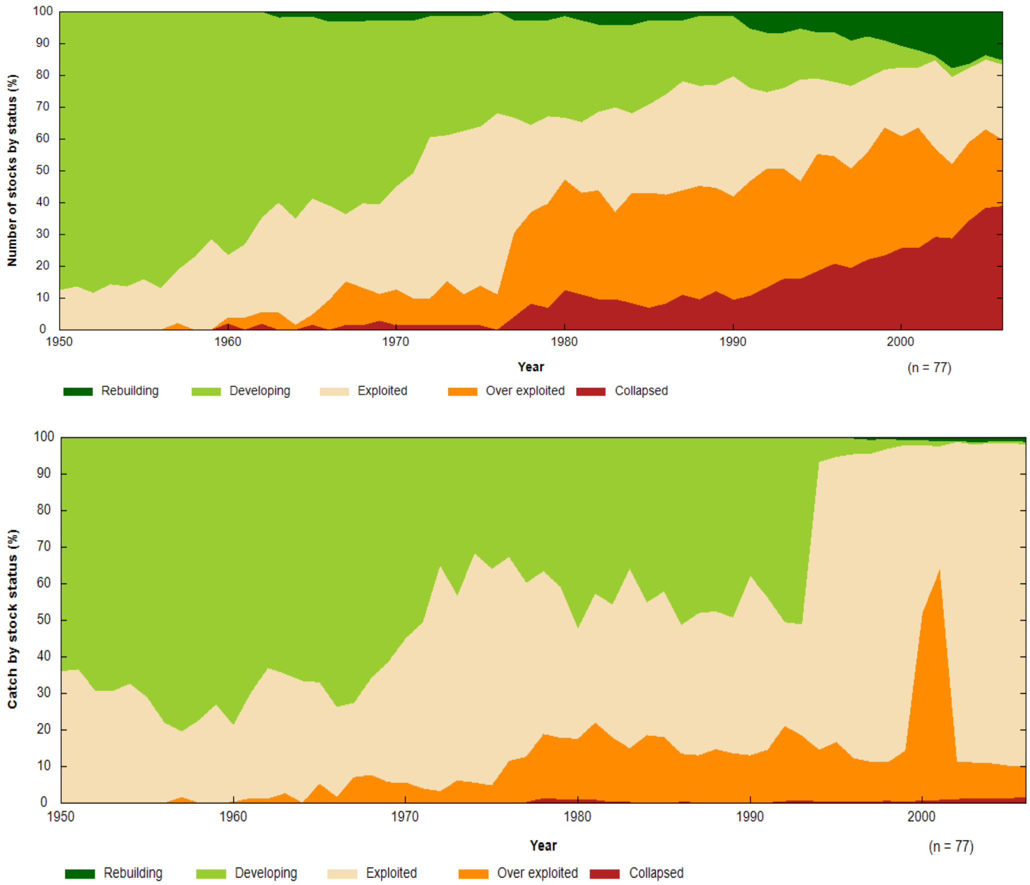


Figure 38. Stock Status Plots for pelagic fish stocks in the CLME

<u>Change in trophic structure</u>

As discussed in the reef ecosystem section, an indicator of the ecosystem impacts of unsustainable fishing practices is a change in the structure of the marine food web, as reflected in changes in the mean trophic level of the catch. This phenomenon - 'fishing down the food web'- occurs with depletion of large predators (high trophic level species) through fishing, leading to a predominance of smaller, low-trophic level species (Pauly et al. 1998). Large pelagic fish species are among the top predators in the ocean. These resources are also intensely targeted by fishing fleets of a number of CLME countries, and for the highly migratory oceanic species, by fleets of other countries in their own EEZs as well as on the high seas. As a consequence, the populations of some of these species have been reduced by fishing, with changes in the trophic structure of the pelagic communities.

Analyses carried out by the UBC Sea Around Us Project for the CLME project showed that the MTI of the landings of pelagic species in the CLME declined steadily between 1950 and 2006 (Figure 39). These analyses relied upon the global database of fish landing assembled and maintained by the FAO. The observed decline in MTI could be attributed to the progressive depletion of top predatory pelagic fish in the CLME, which is consistent with the observed global trend of reduction in large predators in marine ecosystems (Pauly et al 1998, Myers and Worm 2003).

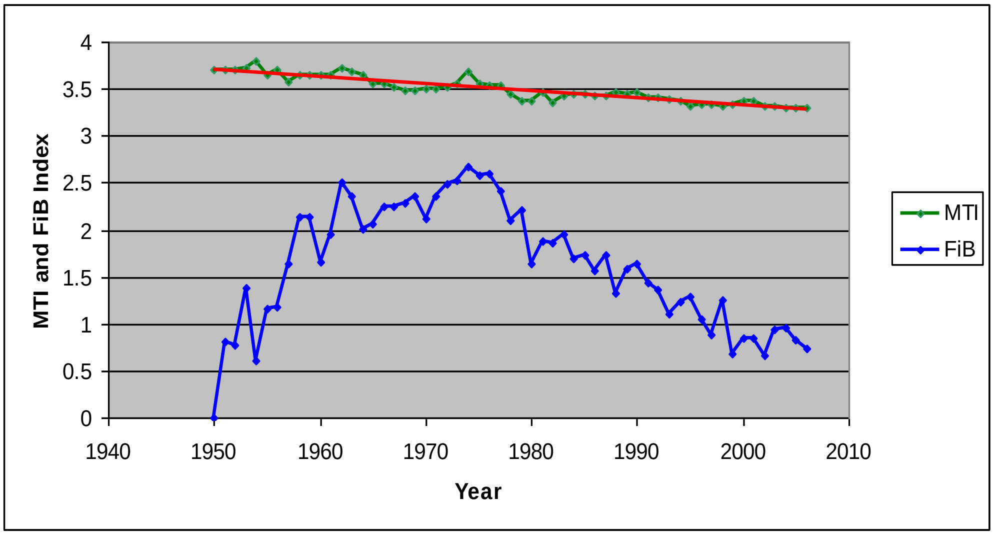


Figure 39. Marine Trophic Index (MTI) and Fishing-in-Balance Index (FiB) for reef species in the CLME

The FiB index increases where geographic expansion of the fisheries is known to have occurred. As shown in Figure 39, the FiB Index for the CLME pelagic resources increased initially, which is consistent with the expansion of these fisheries during this period. As discussed in the reef ecosystem section, the FiB will decrease if discarding occurs that is not considered in the 'catches', or if the functioning of the ecosystem is impaired by fishing (Sea Around Us Project 2010). The marked decline in the FiB Index for CLME pelagic resources, especially from the 1980s accompanied by a steady decrease in annual landings, may reflect the impairment of ecosystem functioning of the pelagic system, as has also occurred for the reef ecosystem.

Threats to biodiversity

Fishing gears such as gillnets, purse seines and longlines used to target large pelagic resources can also catch other animals. The incidence of large quantities of bycatch in pelagic fisheries is of concern globally, especially as this bycatch often includes threatened, endangered and /or protected species such as marine mammals, marine turtles and sharks as well as seabirds (e.g. Arocha et al 2002, Zollett 2009). In the IUCN Red List, all members of the genus *Alopias*, the thresher sharks, are listed as Vulnerable globally because of their declining populations. These downward trends are the result of a combination of slow life history characteristics (hence low capacity to recover from moderate levels of exploitation), and high levels of largely unmanaged and unreported mortality in target and bycatch fisheries. The blue shark is listed as Near Threatened, with decreasing population trend. There is concern over the removal of such large numbers of this likely keystone predator from the oceanic ecosystem. The impacts of fishing activities directed at large pelagic fish resources extend beyond these resources and are linked to other parts of the ecosystem as well.

In Colombia, dolphins, sharks, and sea turtles were reported as bycatch of the tuna fishery; it is necessary to adjust on board practices and legislation to return live sharks to the sea (Puentes Granada 2011). In this country, gillnet, drift gillnet, and hook and line fisheries reported sting rays, sea turtles, and dolphins as bycatch. In the Venezuelan tuna and swordfish fishery in the Caribbean and Western Central Atlantic, a total of 21 shark species have been caught as bycatch during the period 1994-2000 (Arocha et al 2002). The most common species is the blue shark, which represents 30.6% of the total catch in numbers, followed by the blacktip shark which represents 23.7%. Although in most cases sharks are not discarded and fully utilized, as previously mentioned, sharks are particularly vulnerable to fishing pressure and there is concern for their status globally.

Fishing for marine mammals has traditionally been carried out in a number of the islands such as Dominica, St. Lucia, and St. Vincent and the Grenadines. The Caribbean monk seal is now considered extinct by the IUCN, largely through overhunting (Rice 1973). The West Indian manatee once occurred along the nearshore coastal waters of Tobago during the 18th Century. This species is now extinct from around Tobago as a result of local and regional hunting (Khan 2002). The baleen whale, sperm whale, and West Indian manatee are all listed as Vulnerable to extinction on IUCN Red List of Threatened Species.

Socio-economic impacts

Unsustainable fishing and decline in fish stocks have important socio-economic consequences throughout the region. Pelagic fisheries, like reef fisheries, represent a significant source of employment, income and protein for the CLME countries. This is particularly the case for the nearshore pelagic resources. The fisheries sector continues to act as a 'safety-net' for the economy in many of the countries, i.e., when there is a downturn in other sectors, such as tourism and construction, individuals re-enter or increase their activity in the fisheries sector. As a result, there are a high percentage of part-time fishers in many of the countries. Fish is a major component of the diet and the primary source of protein in the countries. Annual per capita fish consumption reaches up to 20 - 30 kg (live wet weight) in several of the countries, for example, in Barbados, Dominica, and Jamaica (FAO 2003). Fishing not only provides nutrition and employment but is also a traditional and cultural way of life for many island communities as well as indigenous communities. Declining fisheries may alter the cultural integrity of these communities.

Particular attention should be paid to the increasing use of conventional food fish such as flyingfish for bait. An important finding of the LAPE project was that, subject to important uncertainties and caveats, the current and planned increases in longline fishing effort directed at large pelagics may have important impacts on bait species and ecologically dependent predators (e.g. dolphinfish). Food security could become an issue for those fishers currently dependent on the coastal pelagic fisheries for food and livelihood. Further examination of this issue is needed before policy decisions are taken (Mohammed et al 2008, Fanning and Oxenford, in press).

Although in some countries fisheries do not make a significant contribution to GDP compared to other sectors, large pelagic resources account for substantial income and foreign exchange earnings in the countries that target these resources, especially in the Lesser Antilles. Exports of fish products from the CARICOM region were valued at over US$250 million in 2000 (FAO Annual Yearbook Fisheries Statistics: Commodities, 2000).

Socio-economic impacts of unsustainable fishing of pelagic resources include loss of employment, reduced food security in communities that depend on fishing, and reduced income and foreign exchange earnings. Further, erosion of livelihoods and employment opportunities in the fishing sector could lead to increase criminal activities and migration towards big cities. This is particularly significant in countries with a relatively high level of poverty (and considering that small-scale fishers are often among the most economically disadvantaged in society), and countries in which the large pelagic fisheries are the dominant fisheries sector. Reduction in the abundance of pelagic fish could also have negative consequences for tourism and recreational fishing, which is growing in the region, and lead to conflicts between fishers and even countries that exploit the same stocks. The fishing industry has made significant investments to exploit the region’s large pelagic resources. Decline of these resources represents a major economic loss to these investors.

4.2.2. Habitat degradation and community modification

Previous assessments in the CLME region have focused on degradation of coastal habitats such as coral reefs, mangroves, seagrass beds, and beaches, with no explicit mention of pelagic habitats. The pelagic ecosystem supports substantial and valuable living marine resources and is also subjected to a range of environmental stresses that can impact these resources.

The major environmental impacts of habitat degradation and community modification of the pelagic ecosystem include:

i. Loss of ecosystem structure and function and loss of biodiversity;
ii. Reduction in fisheries productivity.

Loss of ecosystem structure and function and loss of biodiversity

Degradation of the pelagic ecosystem can occur through large-scale processes such as climate change and ocean acidification as well as localized pollution from a number of substances. While mobile pelagic species are able to avoid localized degraded areas, less mobile species and early life history stages might not have this ability. The impacts of global warming and acidification on the structure and function of the pelagic ecosystem are expected to be severe. A general declining trend in primary productivity with ocean warming was reported by Richardson and Schoeman (2004) and Behrenfeld et al (2006). Most available studies have focused on the impacts on commercial fish stocks. Due to tight trophic coupling, fisheries are adversely affected by shifts in distribution and reduction in prey and in primary productivity (Behrenfeld et al 2006). The latter is generated by strong thermocline stratification inhibiting nutrient mixing.

The impacts of climate change on marine biodiversity was investigated by Cheung et al (2009b), by projecting the distributional ranges of a sample of 1,066 exploited marine fish and invertebrates for the year 2050 using a newly developed dynamic bioclimate envelope model. The projections show that climate change may lead to numerous local species extinction in the sub-polar regions, the tropics, and semi-enclosed seas. These results are very pertinent to the CLME, which lies in the tropics and is semi-enclosed. Because of the complexity and scale of the problems and processes involved, the authors pointed out that the magnitude of these projections was uncertain. Nevertheless, the impacts of climate change on biodiversity could cause ecological disturbances and potentially disrupt ecosystem services in the CLME.

The impacts of pollution on the pelagic habitat are discussed below.

Reduction in fisheries productivity

Marine fisheries productivity is likely to be affected by the alteration of ocean conditions including water temperature, ocean currents, and coastal upwelling, as a result of climate change (IPCC 2007, Diaz and Rosenberg 2008). Such changes in ocean conditions affect primary productivity, species distribution, and community and foodweb structure that have direct and indirect impacts on distribution and productivity of marine organisms. Figure 40 (Belkin et al 2009) shows trends in mean SST (left panel) and SST anomalies (deviation from zero; right panel) in the CLME. A steady warming trend since 1982 is evident, with greater positive SST anomalies (higher temperatures) prevailing since the mid-1990s.

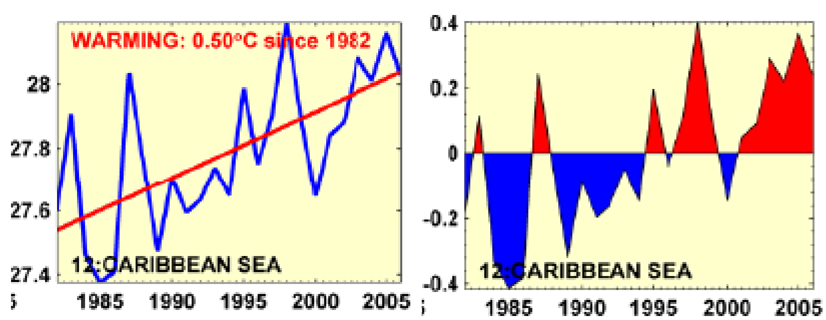


Figure 40. Mean annual SST (left) and SST anomalies (right) for the CLME 1982 – 2006

A global study of the impact of SST changes over the last 25 years on the fisheries yields of 63 LMEs showed warming trends in 61 LMEs around the globe and declining fisheries yields in the fast-warming, more southerly reaches of the Northeast Atlantic in response to decreases in zooplankton abundance (Sherman et al 2009). In the tropics and the southern margin of semi-enclosed seas, species are projected to move away from these regions as the ocean warms up. In another study, Cheung et al (2009a) projected the global pattern of change in maximum catch potential from 2005 to 2055 under the two climate change scenarios representing high- and low-range greenhouse gas emissions. Rising sea water temperatures may have a large impact on the distribution of maximum catch potential (a proxy for potential fisheries productivity) of pelagic and demersal species by 2055 (Cheung et al 2009a). Such a redistribution of catch potential is driven by projected shifts in species' distribution ranges and by the change in total primary production within the species' exploited ranges. The catch potential in the CLME decreases considerably under the high range scenario (Figure 41).

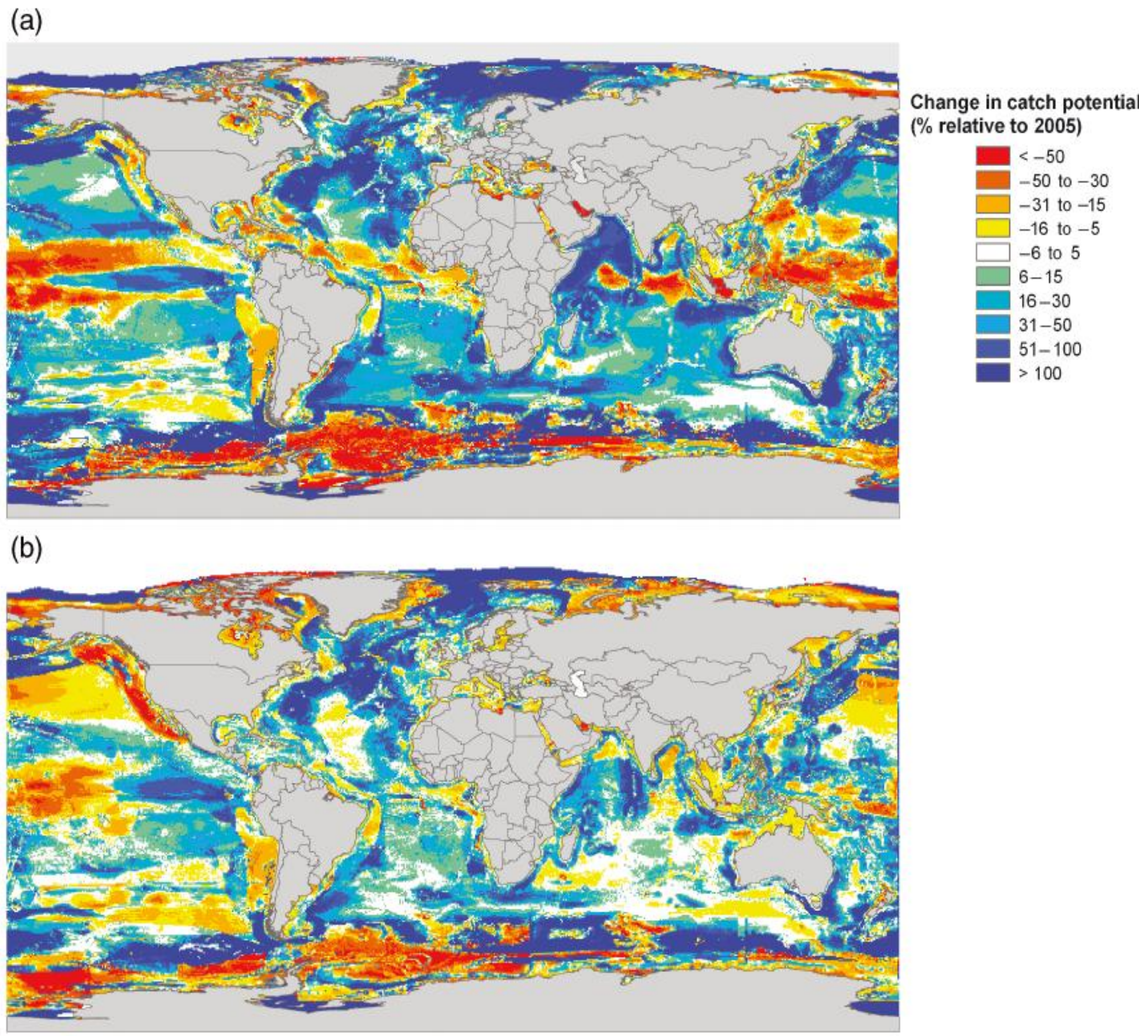


Figure 41. Change in maximum catch potential (10-year average) from 2005 to 2055 under two climate change scenarios

(a) High range (b) Low range. (Cheung et al 2009a)

Changes in the location and/or strength of ocean fronts and other oceanic features may also affect the abundance of pelagic fishes. However, changes in availability to the local fishing fleet are more likely to occur than are large scale changes in abundance (Mahon 2002). Ocean currents are also related to upwelling that enhances nutrient enrichment and hence primary and secondary production that may support fish stocks. In the Caribbean, upwelling areas off the Guianas-Brazil Shelf, downstream of island passages, and off Venezuela are known to influence fishery production and may also be affected by climate change (Mahon 2002).

Most fishery resources of importance to CLME countries have early life history stages (eggs and larvae) that drift in the plankton (e.g. most reef fishes, lobster, conch, all pelagic fishes). Any impacts on the habitats in which they spend their early life history stages can affect the numbers of recruits that survive to enter the fishery. Many species that depend on ocean currents for reproduction and food will be affected by increasing SST. Altered circulation patterns and rising SST will have negative impacts on marine organisms critical to the ocean food web.

While to date no information has been found on the impacts of climate change on ocean circulation and pelagic fish in the CLME, evidence has been documented for other regions. For example, in the Maldives, variations in tuna catches are especially significant during El Niño and La Niña years. This was shown during the El Niño years of 1972/1973, 1976, 1982/1983, 1987 and 1992/1994, when the skipjack tuna catches decreased and yellow fin increased, whereas during La Niña years skipjack catches increased, whilst catches of other tuna species decreased (MOHA 2001). Changes in migration patterns and depth are two main factors affecting the distribution and availability of tuna during those periods, and it is expected that changes in climate would cause migratory shifts in tuna aggregations to other locations. The two main effects of climate change on tuna fishing are likely to be a decline in the total stock and displacement of the stock, both of which will lead to changes in the catch in different countries.

In recognition of the uncertainties of climate warming effects on fisheries yields and the lack of the capacity for conducting annual assessments of a large number of marine fish stocks in many developing countries, it has been recommended that countries implement precautionary actions to protect present and future fisheries yields with a cap-and-sustain strategy aimed at supporting longterm food security and economic development needs, and move toward the adoption of more sustainable fisheries management practices (Brander 2007, Sherman et al 2009).

Socio-economic impacts

Degradation of the pelagic ecosystem results in a range of adverse socio-economic impacts, linked mainly to the tourism and fisheries sectors. The services provided by the CLME pelagic ecosystem are an important source of food, livelihoods and revenue from fisheries and tourism in the bordering countries. Pelagic habitat degradation and community modification are likely to have severe socio-economic consequences for those nations and communities that depend heavily on commercial and recreational fishing and tourism for their social and economic viability. As previously mentioned, one of the consequences of habitat degradation is reduced fisheries productivity, the socio-economic impacts of which have been discussed in the section on unsustainable fishing.

Caribbean tourism is linked in many of the countries with clear, blue seas and white sandy beaches. Tourism revenues are often directly impacted by habitat degradation because of the loss of amenity value for activities such as recreational fishing, swimming, and dive tourism. Habitat degradation represents a loss of income and employment opportunities in the fisheries and tourism sectors in the medium and long-term.

With limited opportunities for economic diversification in the small islands, habitat degradation can have severe socio-economic consequences for the Insular Caribbean (UNEP 2004a, 2004b). Habitat degradation and community modification can reduce existing income and foreign exchange from other related sectors and inhibit investment. Other socio-economic impacts of habitat degradation include loss of aesthetic, educational and scientific values and loss of cultural heritage.

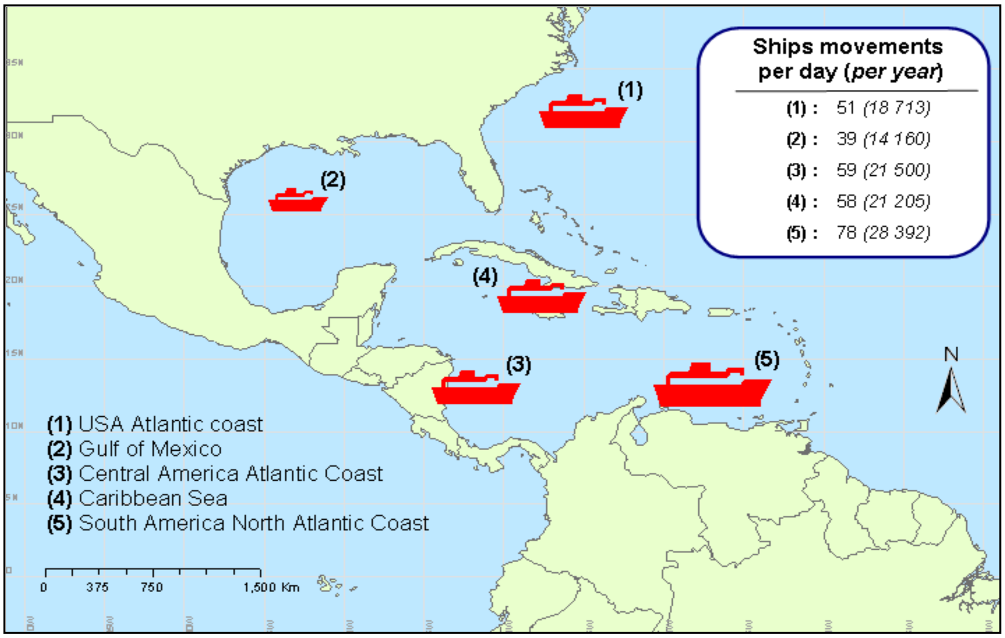
4.2.3. Pollution

In the literature on pollution in the Caribbean Sea, the pelagic ecosystem is generally not treated separately from the reef ecosystems, except where particularly severe impacts have been observed. Pollution is discussed in the reef section and also applies to the pelagic ecosystem. In addition to the main pollutants described for the reef ecosystem (nutrients and sediments), hydrocarbons and other hazardous substances pose a significant threat to the pelagic system. The high ship traffic and oil and gas operations present a high risk of pollution of the pelagic environment from these substances.

The Panama Canal makes the Caribbean Sea, particularly in the north, an area of intense maritime cargo freight traffic between the Atlantic and Pacific Oceans. During the period 2003-2004, a study was conducted on the movement of ships in five areas of the WCR, with information from Lloyd´s Maritime Information Unit (Vila et al 2004). Results showed a total movement of 103,970 ships and averages of 8,664 ships per month and 285 ships per day. The three areas with the highest number of movements were all within the CLME, with the highest movement taking place on the Atlantic Coast of South America with 28,392 ships per year (Figure 42), associated mainly with the Panama Canal. This movement does not identify the types of ships involved, although it is known that much of the ship traffic in the region is associated with export of petroleum. The Caribbean Sea is only second in oil traffic to the Persian Gulf.

The information on shipping traffic underscores the potential danger posed to the WCR by the risk of oil spills and other hazardous substances, as well as by invasive species. Shipping accounts for the introduction of significant quantities of ballast water into the Caribbean Sea. In 2005, six million tonnes of ballast water were poured into the Caribbean Sea, of which 84% came from international shipping. About 7 million barrels of oil are discharged annually from tank washings.

Figure 42. Daily and yearly ship movement in the five areas in the Wider Caribbean in 2003



An estimated 90% of the hydrocarbon pollution in the WCR originates from land-based industrial sources and activities (UNEP-RCU/CEP 2011). The main causes of elevated hydrocarbon concentrations in the region are leaching of drilling oils and other residues from the oil industry, vandalism, shipping traffic discharges (mainly bilge oil and fuel oil sludge), and accidents (INVEMAR 2007, PNUMA 2007).

The CLME has major oil producing countries (Mexico, Colombia, Venezuela, USA, and Trinidad & Tobago) and important ports for oil refining. A large number of offshore oil platforms operate in the region (e.g. off Venezuela, Trinidad and Tobago, Colombia), with offshore drilling explorations in other areas such as off Cuba and Jamaica. These offshore platforms are potential sources of pollution from oil and other substances. Produced water discharged into the sea forms "plumes", which drift with the tides and the winds, carrying pollutants up to many kilometres away. This water is frequently contaminated with traces of dissolved and particulate petroleum and other substances such as dispersants, anticorrosives and biocide. Estimates of fats and grease and dissolved and dispersed petroleum hydrocarbons for the Magdalena River/Dique Canal of Colombia were 16,300 tonnes per year and 676,000 tonnes per year, respectively.

Runoff from mining, in particular in areas where mineral beds are not covered, is a source of toxic and hazardous pollutants that eventually end up in coastal ecosystems. Bauxite mining is particularly important for the economies of Jamaica, Suriname and Guyana and to a lesser extent, the Dominican Republic and Haiti. Bauxite extraction is a source of serious pollution in coastal areas of these countries, although in Jamaica the bauxite waste is placed in special dumps (UNEP-RCU/CAR 2011). Other mining operations in the region include the bed extraction for nickel oxide production, which takes place mainly in Cuba and Dominican Republic.

The release of untreated or partially treated domestic wastewater (including sewage) into coastal areas is a major concern in the region. In a review of domestic wastewater management in the WCR within the framework of the GEF Caribbean Regional Fund for Wastewater Management (CReW) Project (Cimab 2010), it was shown that significant quantities of domestic wastewater are discharged into a number of coastal hotspots in the following countries: Colombia (Cartagena Bay), Jamaica (Kingston Harbour), Nicaragua (Bluefields Bay), Trinidad & Tobago (Gulf of Paria), Venezuela (Gulf of Cariaco), Guyana (Georgetown) and Suriname (Paramaribo). The highest flow was reported in Trinidad and Tobago (T&T), followed by Colombia and Venezuela (Figure 43). Despite wastewater treatment facilities, there is constant discharge of insufficiently treated domestic wastewater, including sewage, into the sea reflecting the poor performance of these systems (Figure 44). Hot spots in Jamaica, followed by Colombia and Trinidad show the highest proportion of sewage treated, which those in Nicaragua and Venezuela show the lowest proportion. It is estimated that less than 20% of sewage is treated in the LAC region (UNEP 2003), with most of it flowing untreated to rivers and the sea (Martinelli et al 2006, PNUMA 2007).

Pollution in the CLME also arises from areas outside of the region. Industries such as the exploitation of hydrocarbons, gold, aluminium, and timber, as well as large scale agriculture on the South American continent have implications for the introduction of harmful effluents and sediments to the Caribbean Sea by outflow of the continental rivers that are outside the CLME region (Orinoco, Essequibo, and Amazon). Effluents from gold mining, mercury by-products, cyanide and other industrial waste are of concern in the region, as expressed by Grenada. Many of these countries, however, lack the technical capacity to conduct the required analyses to detect these materials in their respective EEZs. In Grenada, flotsam identified on the southern and eastern shores (including huge tree logs) is thought to have originated from South America. Some of this floating material serves as FADs that attract species such as flyingfish, dolphinfish, and mackerels, which increases the vulnerability of these resources to fishing.

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Figure 43. Domestic wastewater flow discharges into WCR hot spots

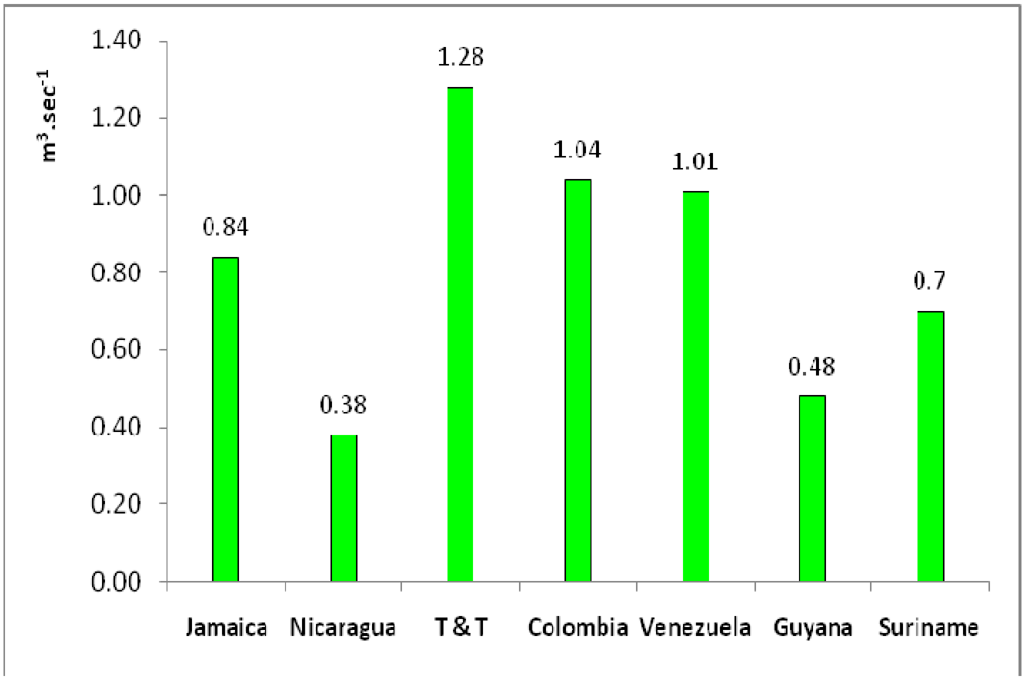
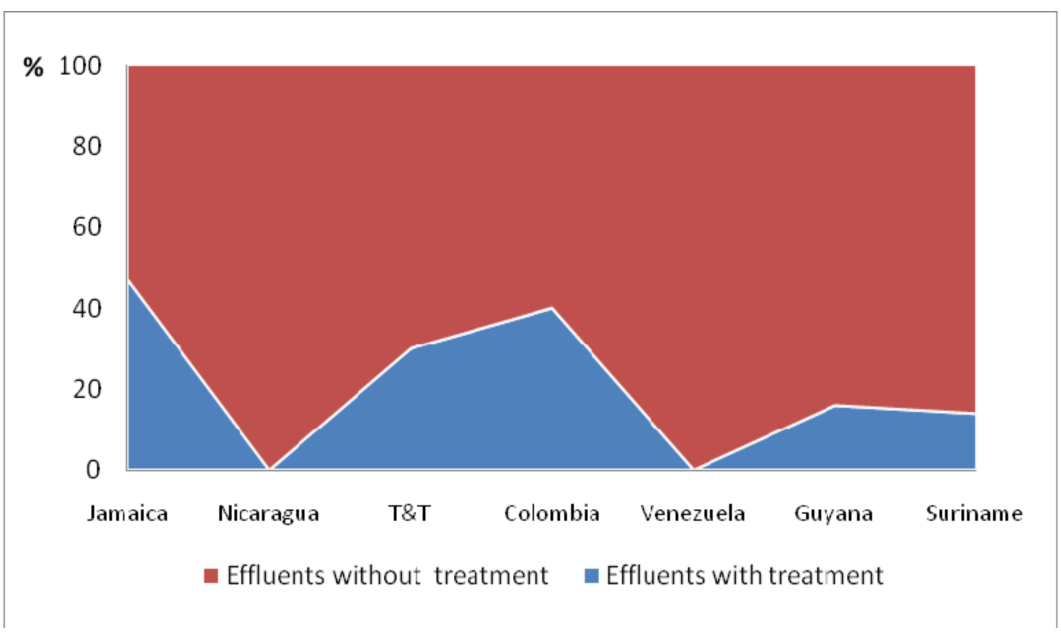


Figure 44. Percentage of sewage subjected to some treatment in WCR hotspots



There is also increasing concern about the influence of atmosphere/ocean linkages on the marine environment (GESAMP 2001). This influence has been demonstrated in the atmospheric transport of dust to the region from North Africa (USGS 2000, UNEP/GEF 2002). Data from Barbados, Trinidad and Tobago, and Jamaica suggest that POPs originating from the Sahel region of North Africa reach the Caribbean in air currents (UNEP/GEF 2002). These countries apply large amounts of pesticides, including those banned in the Caribbean and the USA.

The major environmental impacts of pollution of the pelagic ecosystem include:

i. Deterioration of environmental quality;
ii. Threats to living marine resources.

Deterioration of environmental quality

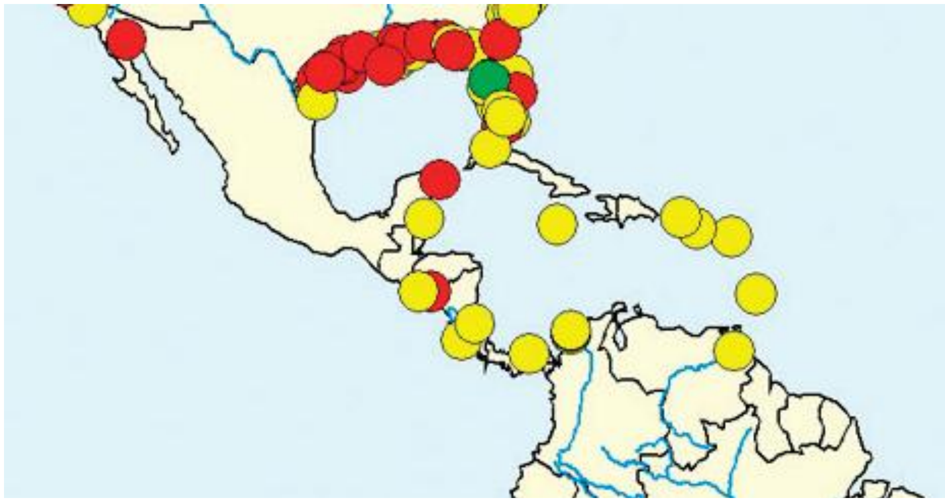
Sewage (domestic and industrial), heavy metals, hydrocarbons, sediment uploads, and agrochemicals are the most important sources of land-based pollution to the Caribbean Sea, with invasive species, marine debris, and thermal contamination also being threats to the health of the most important coastal and offshore ecosystems of the region (Gil-Agudelo and Wells, in press). In the pelagic ecosystem, pollution reduces environmental quality of the water column and can have severe impacts on phytoplankton and zooplankton production that forms the base of pelagic food webs, and on planktonic early life history stages of fish and invertebrates.

Within the past 50 years, eutrophication has emerged as one of the leading causes of water quality impairment. Two of the most acute and commonly recognized symptoms of eutrophication are harmful algal blooms and hypoxia (low oxygen concentration), which are common throughout the region. High inputs of nutrients from sewage and agricultural fertilizers have promoted hotspots of eutrophication, increased algal and bacterial growth, fish kills, and oxygen depletion in the water column in some localized areas (UNEP 2004a, 2004b). For example, Kingston Harbour has experienced increasing eutrophication for decades as a result of sewage pollution, mainly from surrounding towns and from ships (UNEP-CEP/RCU 1998, Webber and Clarke 2002). Havana Bay, which receives about 300,000 m^3 per day of urban/industrial non-treated sewage, is strongly influenced by algal blooms, including frequent red tides (Beltrán et al 2002).

Selman et al (2008) identified 415 eutrophic and hypoxic coastal systems worldwide, of which a number of areas of concern were identified in the CLME (Figure 45).

Oil pollution can have major impacts on the pelagic environment, particularly in cases of major oil spills. Coastal areas near to industrial centres show significant petroleum and heavy metal concentrations in water and sediment, for example, in Cuba, Dominican Republic, Jamaica, and Trinidad (Beltrán et al. 2002).

Figure 45. Hypoxic and eutrophic coastal areas in the CLME



(Yellow: areas of concern; Red: documented hypoxic areas; Green: systems in recovery)

The impact of oil spills was considered severe in the Venezuela and Colombian areas by GIWA, due to widespread and frequent contamination by hazardous spills. Data from UNEP-IOC/IOCARIBE CARIPOL Programme indicate that the concentration of dissolved or dispersed petroleum hydrocarbons are generally low in offshore waters, while relatively high levels are found in semi-enclosed coastal areas. In Cartagena Bay (Colombia), petroleum exploration, extraction, refinement, and spills from ships represent 80% of the total petroleum discharged in the region (INVEMAR 2001).

Sewage contains a wide variety of pollutants at highly variable concentrations and volumes. The chemical constituents of sewage range from trace metals to complex organics such as polycyclic aromatic hydrocarbons, pesticides, surfactants, and drugs and their metabolites. Other components of sewage include nutrients, microbes, and pathogens (Gil-Agudelo and Wells, in press), which could harm marine habitats and organisms as well as humans. The discharge of non-treated sewage introduces significant levels of microorganisms into the marine environment. Microbiological pollution of the water column is a serious concern in the CLME region, and was considered from moderate to severe by GIWA, suggesting little compliance with International Standards. These impacts may be localized, however, and the degree of transboundary impacts is not known.

There have been moderate impacts from solid wastes in the region. The composition of solid waste continues to change from mostly organic to inorganic, non-biodegradable material, such as plastics. The countries have limited capacities for the collection and final disposal of industrial, municipal, and ship-generated solid wastes. Much waste is disposed of in mangrove swamps, drainage channels, and along riverbanks, consequently polluting rivers, streams, and eventually the coastal waters, particularly during the rainy season. An associated problem is the leaching of contaminates from solid wastes such as motor vehicles.

Threats to living marine resources

Oxygen depletion caused by eutrophication can lead to fish kills in the water column in some localized areas (UNEP 2004a, 2004b). In 1999, fish kills arising from eutrophication virtually closed down the local fishery in Grenada; this seems to be now occurring annually. Fish kills, as occurred in the Windward Islands in 2000, have also been linked to bacteria introduced in sediments as a result of flooding in the Orinoco Basin (Hoggarth et al. 2001). These transbounday impacts are likely to be more pronounced during the rainy season.

Oil concentrations of 500 ppm or even less can inhibit the growth of phytoplankton and pelagic bacteria. Their effect also extends to the sea bed at a distance which depends on the relief of the seabed and existing oceanographic conditions. Previous oil spills have caused significant mortality of aquatic and avian species with many contaminated carcasses observed on beaches in the Venezuela/Colombia area (UNEP 2006).

Contaminants such as mercury can move through and accumulate in higher levels of marine food chains, including in humans who are at the top of some of these chains. This is of concern in large pelagic species, which are among the top predators in the ocean. Widespread mercury concentrations along the Caribbean coast of Central America suggest that this pollutant is being carried through the region by ocean currents (Gil-Agudelo and Wells, in press).

Total mercury concentration was determined in the tissues of pelagic fishes from the Gulf of Mexico, with a special emphasis on apex predators (Pelagic Fisheries Conservation Program 2006). Highest mercury levels were observed in blue marlin, carcharhinid sharks and little tunny, ranging from ~1.0 to 10.5 ppm. Moderate to low concentrations (<1.0 ppm) were observed in blackfin tuna, cobia, dolphin, greater amberjack, king mackerel, wahoo, and yellowfin tuna.

Litter, mainly composed of plastic, accumulates in beaches and shallow waters, and can cause considerable harm to fish, turtles, birds, and marine mammals by entanglement (particularly in fishing gear), smothering, and ingestion. Floating debris in Bahamian waters contributed to unsuccessful reproduction and death of sea turtles, marine mammals, and sea birds in this country's waters (BEST 2002).

Socio-economic impacts

The socio-economic consequences of pollution vary from slight to severe in the region (UNEP 2004a, 2004b, 2006). These include a decrease in the value of fisheries products through contamination, and loss of economic and aesthetic value of coastal areas. Chemical and organic compounds released into the environment by industrial and agricultural activities present a permanent threat to human health.

HABs are frequently the cause of very serious human illness when the biotoxins produced are ingested in contaminated seafood. The illnesses most frequently associated with marine biotoxins include paralytic shellfish poisoning and ciguatera poisoning. High bacterial counts have been detected in some bays in the region (UNEP 2004a), especially where there are large coastal populations and high concentration of boats. Microbiological pollution from sewage is a threat to human health; in some areas downstream coastal communities have a high prevalence of gastrointestinal and dermal ailments (UNEP 2006). Emissions of heavy metals pose a serious risk to human health and living marine resources. Bioaccumulation of some pollutants such as POPs and heavy metals in the tissue of marine organisms that are consumed by humans can also have serious impacts on human health. This is of particular concern in large pelagic species that are top predators in the marine food chain. Some of these species such as tunas are known to have high levels of mercury in their flesh.

Pollution has also diminished the aesthetic value of some areas, impacting on recreational activities and reducing revenue from tourism (UNEP/CEP 1997). The economic cost of addressing pollution (e.g. clean up of oil spills, adoption of new technologies) and of medical treatment of pollution-related illnesses could be very significant. Data (or access to data) on the socio-economic impacts of pollution is very limited in the region.

5. CAUSAL CHAIN ANALYSIS

The Global International Waters Assessment (GIWA) developed a priority setting mechanism for actions in international waters (Belausteguigoitia 2004). Establishing priorities for actions implies not only an assessment of the severity of the problems but also an analysis of what can be done to solve or mitigate these problems. Understanding the root causes of these problems is particularly relevant for the further analysis of actions. Causal Chain Analysis (CCA) traces the cause-effect pathways of a problem from the environmental and socioeconomic impacts back to its root causes. A causal chain is a series of statements that link the causes of a problem with its effects. Its purpose is to identify the most important causes of priority problems in international waters in order to target them by appropriate policy measures for remediation or mitigation. By understanding the linkages between issues affecting the transboundary aquatic environment and their causes, stakeholders and decision makers will be better placed to support sustainable and cost-effective interventions.

The components of a conceptual CCA model for a particular concern include:

Socio-economic impacts:	The adverse effect of an issue on human welfare (e.g. increased costs of water treatment or illnesses due to pollution (discussed in previous section under each issue).
Environmental impacts:	The adverse effects of an issue on the integrity of an aquatic ecosystem (e.g. loss of aquatic life as a result of eutrophication). (discussed in previous section under each issue).
Immediate causes:	The physical, biological or chemical variables that have a direct impact on an issue; for example, enhanced nutrient inputs in the case of eutrophication.
Sector activities:	Include two components- the activities in the different economic sectors that provoke the immediate cause (e.g. in the agricultural sector, the excessive application of certain kinds of pesticides) and the decisions made by firms, farmers, fishermen, households, government officials or politicians (socio-economic agents in general) that directly or indirectly produce the negative impact (e.g. farmers´ decision to use a highly persistent pesticide).
Underlying causes:	Includes two components - Resource uses and practices; and Social, economic, legal and political causes.
Root causes:	The key factors, trends, processes or institutions that influence a situation, issue, or decision that propel the system forward, and determine a scenario’s outcome (e.g. governance and culture).

The CCA presented below for the three priority transboundary issues in the CLME are based on the previous thematic reports and on the extensive list of causes identified by the TTT in January 2010 (Annex 5). The list of immediate, underlying, and root causes developed by the TTT were grouped under major categories because of overlaps and redundancies, and the practicality of addressing each one individually. In some instances it was not possible to separate the available information for reef and pelagic ecosystems, and for completeness, this information is repeated in both CCAs.

5.1. Reef Ecosystem Causal Chain Analysis

5.1.1. Unsustainable exploitation

Sectors that contribute to unsustainable exploitation: Fisheries; tourism; coastal urbanization (high demand for employment and seafood, recreational fishing)

Immediate causes

Catches beyond sustainable levels, including immature and/or spawning individuals

Humans can negatively affect coral reef fish and invertebrate populations directly when catches are so large (beyond MSY) that the remaining stock is insufficient to replenish the population. Catches of large quantities of immature/undersized and spawning individuals (such as lobster, conch, and snappers and groupers that are heavily fished when they aggregate to spawn) could also cause declines in the affected stocks. This could lead to growth and recruitment overfishing and declines in spawning stock biomass. Many reef fish are very vulnerable to high fishing pressure because of their life history strategies. Among these are the valuable snappers and groupers that have been particularly targeted along with lobster and conch. Reef fisheries are generally open access and within easy reach of artisanal fishers, who predominantly target these reef resources. As these nearshore reefs become overexploited, the fisheries have expanded to offshore areas, where there is already evidence of overfishing. Catches of all major reef species in the CLME have declined in the last few years despite increasing fishing effort, a clear sign of unsustainable exploitation. Historical and continuing intense exploitation of reef resources has resulted in a substantial number of overexploited or collapsed reef stocks, and declines in mean trophic levels throughout the CLME. Sea turtles have suffered the same fate. As a consequence of legal and illegal capture, killing of gravid females on nesting beaches, and egg collection, marine turtles are now threatened in the WCR.

Bycatch and discards

Reef fish communities include an immense number of species, not all of which are desirable by fishers, but which serve important functional roles within the reef ecosystem. Over the last century, fish traps have been responsible for a large portion of catch in the Caribbean. Traps are notable for their high level of bycatch of many juvenile and narrow-bodied fishes. Bycatch of young of commercially important species also contributes to adult stock declines. Despite the high level of bycatch, most Caribbean artisanal fishers retain the majority of fish caught. Estimates of landings and discards in Caribbean countries are substantial, with Belize, Dominican Republic, Guatemala, and Haiti having the highest discard rate (Annex 6). These estimates need to be verified at the country level. As the data in Annex 6 are based only on records where the volume of discards is available certain fisheries are not included in these estimates.

Incidental capture of marine turtles may be the most important factor limiting their recovery in some areas. More than half of the marine turtle mortalities or injuries recorded in Guadeloupe in the period 1999-2002 were attributable to fisheries interactions. In Trinidad, about 3,000 gravid leatherbacks have been estimated to be accidentally caught in gill nets offshore from nesting beaches every year (Lee Lum 2003).

Underlying causes

Open access nature of fisheries

Caribbean reef fisheries are largely open access - anyone can enter the fishery and there are no set limits on the number of fishers (although unprofitable catches could eventually force fishers out or discourage others from entering). The ease and low cost of catching reef fish encourages more persons to enter the fishery. This is exacerbated by the limited employment opportunities in other sectors. Reef fisheries are characterized by an enormous number of fishers (most of the CLME's fishers exploit reef resources). Illegal fishing by foreign fleets in the Caribbean Sea also contributes to excessive pressure on the fisheries stocks. This is difficult to control because of the lack of a regional governance framework for transboundary fisheries and insufficient capacity of the countries for monitoring and surveillance of their respective EEZs.

Fishing overcapacity

Under open access conditions in the reef fisheries, fishing fleets have expanded far beyond the size needed to economically catch the available fishery resources. In the 1950s and the 1960s several Caribbean countries undertook major fishing capacity expansion, fleet mechanization and acquisition of advanced technology and fishing gear. Fishing capacity for lobster is much larger than is needed in most Caribbean countries, with the possible exception of a few countries with effort-controlled fisheries. Fisheries expansion has had considerable impacts throughout the region. Declines in CPUE, reduction in the size of fish caught and changes in species composition are prevalent in Caribbean fisheries. Despite declining CPUE, fishing fleets continued expanding throughout the 1990s in many countries in the region. As a result, a substantial number of reef fish stocks are overexploited or have collapsed.

Destructive fishing methods

All fishing methods have an impact on the target resource and may also affect non-target species and the wider marine environment. These practices could be categorized as:

- Destructive fishing practice, or destructive use, e.g., when a gear is used in the wrong habitat, such as bottom trawls in seagrass, macro algae or coral beds; and

- Destructive methods, the impact of which are so indiscriminate and/or irreversible that they are universally considered "destructive" in any circumstances.

Here, the focus is on the second category (the first is discussed in the habitats CCA). Destructive fishing methods include the use of explosives, poisons and other harmful substances such as bleach, as well as non-selective fishing gear (e.g. small-meshed nets and fish traps) can accelerate resource declines. The issue of ghost fishing by lost or abandoned gear is an issue that remains largely unaddressed in the Caribbean. Destructive fishing methods are nonselective for the fish and other species they affect. In addition to the fishing gear itself, damage is also caused to fish habitats by boat anchors and groundings, which indirectly affect the fisheries resources. The catching and discarding of large quantities of non-target species and juveniles of commercially important species are unsustainable practices that also contribute to fish stock declines.

Illegal, Unregulated, and Unreported fishing

IUU fishing contributes to overexploitation of fish stocks and hinders their recovery. It also introduces uncertainties in stock assessment as total fishing effort and catches are not known. The Caribbean countries generally do not have the required capacity or financial resources for surveillance, monitoring, and enforcement. Reef fisheries are particularly difficult to monitor because of their predominantly small-scale nature and numerous and diffuse landing sites. Moreover, Caribbean reef fisheries are largely open access and unregulated and much of the catches are likely to be unreported, especially for the artisanal sector. As a consequence, artisanal catches are seldom registered and are invisible in the national or local economy, which makes it difficult to develop adequate policies and management plans for sustainable fisheries or to improve surveillance and enforcement. There is also illegal foreign fishing in the EEZs of some countries. Where regulations exist in the region (such as for turtles, conch and lobster) in many cases they are not very effective because of poor surveillance, monitoring, and enforcement of fishing activities and regulations.

Deficiencies in institutional, policy, and legal framework

Despite the existence of a number of relevant international binding and non-binding frameworks for fisheries management (e.g. LOSC, FAO Code of Conduct), there is no regional framework that specifically deals with transboundary reef resources. Moreover, institutional capacity to manage the region's fisheries at the national and regional levels is inadequate. There is a general lack of harmonized regulations for transboundary fisheries at local, national and regional levels. Participation of the countries in collaborative management of transboundary resources is generally low due to the absence of. Management of the reef fisheries is complicated by factors such as the absence of delimited EEZ boundaries in some of the countries (Lesser Antilles), multiple user conflicts arising from marine-based tourism, and unregulated fishing (Cadogan 2006).

While all the countries have fisheries regulations, these are often not effectively implemented and enforced. There is a chaotic policy in allocating access rights where such policies exist, since there is the tendency to distribute more fishing licenses and permits than are necessary to achieve the allocated catches.

Limited institutional, human, and technical capacity

Government institutions have limited capacity to mitigate the adverse effects of development on coastal areas or to resolve conflicts over the allocation of common resources. Important elements lacking or limited in most countries are: leadership and continuity; trained staff; inter-agency coordination, including formal mechanisms for resolving resource conflicts; fully participatory processes; and an ability to enforce regulations. The capacities of fisheries departments are limited with respect to personnel, equipment, and training. Some countries have experimented with restructuring to overcome institutional problems such as inter-agency commissions or semi-autonomous units. But without real improvements in capacity accompanied by mechanisms to ensure the financial sustainability of fisheries management, institutional restructuring has had limited effect on how these resources are managed.

Ineffective enforcement, monitoring, and surveillance

In general, legislation at national and local scales exists in the countries, but the lack of or poor enforcement is a driver for unsustainable practices. The virtual lack of maritime surveillance and enforcement, particularly in remote areas, is a widespread institutional problem that has left several locations vulnerable to illegal activities. Non-compliance with fisheries regulations by foreign fleets, due to inadequate monitoring and surveillance, is also of concern in the region. Limited financial resources and human capacity to devote to fisheries assessment and management result in non-existent or limited monitoring, surveillance and enforcement of existing national policy and legislation, and limited implementation of the relevant Multinational Environmental Agreements (MEAs). Despite the existence of fisheries regulations, these are not efficiently applied, and there is inadequate monitoring, surveillance, and enforcement due to inadequate capacity and other factors (such as corruption).

Inadequate financial resources

Caribbean countries often lack the required financial resources for fish stock assessment, management, surveillance and enforcement. Fisheries resources are freely available, common property and innovative approaches are required to ensure that adequate funds are available for effective management of the region's resources. Among such approaches is payment for ecosystem services, which is still in its infancy in the region. Despite limited financial resources, Governments commonly provide enormous subsidies that are harmful to the very resources that form the basis of the targeted programmes.

Perverse incentives

Perverse incentives (e.g. harmful fishing subsidies) have been a major driver behind the overexpansion of the region's fishing fleet. Huge subsidization programmes in the 1970s, involving loans for vessels, gear purchases and fuel tax rebates, were implemented in several Caribbean countries (Mohammed 2003). This has helped to increase fishing effort and promote fishing overcapacity. Estimates of good and bad fishing subsidies in CLME countries are given in Annex 7. Bad subsidies are far outweighed by incentives for sustainable fisheries (good subsidies). The total value of (non-fuel) bad subsidies (e.g. for boat building) in 21 CLME countries was estimated in 2000 at about US$252 million, which was five times greater than the value (about US$49.5 million) of good subsidies (e.g. for management and surveillance) (Sumaila and Pauly 2006). Perverse incentives continue to exist throughout the region, and include fuel rebates and tax concessions on fishing equipment.

Improvements in technology

Improvements in technology (e.g. more efficient vessels and gear, modern fish-finding equipment and navigation systems) serve to increase pressures on fish stocks, especially those in previously inaccessible offshore areas. The fisheries expansion in many of the CLME countries that occurred in the 1970s and 1980s, not only were larger vessels acquired, but also advanced technology that help with navigation, fish finding and catching, and cold storage of the catch on board that allowed vessels to remain longer on the fishing grounds, among other benefits. Even simple changes in gear and equipment, such as the use of SCUBA in lobster fishing, can effectively increase the fishing pressure on the stocks. In the CLME region, government subsidies have promoted the acquisition of advanced technology.

Inadequate data and information

Reliable data and information on the reef fisheries are particularly scarce because of their artisanal and informal nature. Reef fisheries are characterized by a high diversity of species and gear, diffuse landing sites and numerous small-scale fishers – which all complicate data collection and analysis. Moreover, species are often misidentified or not identified; in the latter case, they are reported as mixed, miscellaneous, or 'nei' – this group comprises a substantial proportion of the CLME's total annual catch. Inadequate or unreliable data introduces high uncertainty about the status of even the most important fish stocks. Inadequate data is often cited as a serious limitation in stock assessments of reef living resources (e.g. by CRFM). This issue also prevents the development of effective and harmonized fisheries management measures for transboundary resources.

Despite initiatives to establish data collection systems and conduct stock assessments in the region, and the obligation of countries to report their catches to relevant organizations, significant gaps persist in data and information required for effective management of the CLME's reef fisheries resources. There is an absence of a centralized and coordinated regional database and limited national databases. Further, language and cultural barriers often constrain the sharing of data and information at the sub-regional and regional levels. Unless urgent steps are taken to collect sufficient data to ensure that resources are used responsibly, there is a high risk that landings will continue to decline (WECAFC 2003). The move towards more integrated, holistic approaches to living marine resources management has revealed major gaps in the knowledge required to implement these approaches. Where scientific knowledge is available, it is often poorly communicated to, and understood by policy-makers and the public.

Root causes

Poor Governance

Poor or inadequate governance is often cited as one of the root causes of fisheries overexploitation. Efforts have been made to protect and preserve the coastal and marine resources of the Caribbean Sea through a number of regional and international conventions and subsequent legislative frameworks. However, at the national level, the administration of the relevant legislation (where it exists) is often scattered across several governmental agencies with weak institutional provisions for the coordination of environmental initiatives across the various sectors. In most countries, stakeholder consultation and participation in governance remain fragmented and weak, despite efforts to address this problem and recognition of its potential role in effecting new and more successful ways of managing fisheries systems (Lane and Stephenson 2000, Mahon et al 2008).

These issues are even more pronounced at the regional level. Reef fisheries are not currently served by a working international governance mechanism (such as ICCAT for the large pelagic fisheries), although specially protected reef associated species come under the SPAW Protocol. Relevant Bodies at the regional level are WECAFC and Caribbean Fisheries Management Council, which have programmes for specific resources (e.g. regional assessment and management of conch and lobster). At the sub-regional level CARICOM/ CFRM and OSPESCA also have programmes related to the assessment and management of specific resources. Some countries have difficulty taking part in these processes to the extent required for successful management.

There is limited co-ordination, collaboration, and harmonization among the numerous players and programmes in the Caribbean for management of transboundary living marine resources. This is clearly demonstrated in the regime for management of sea turtles, which shows enormous variation from country to country in the quality of management regimes, data collection, population monitoring and controls on exploitation (Bräutigam and Eckert 2006). Transboundary living marine resources require coordinated and harmonized governance structures and policy cycles that operate at the appropriate geographic scales, from local, national, sub-regional, regional, and where appropriate, global scales, with appropriate linkages between them. Current thinking on good LME governance suggests that it is more appropriate to approach governance interventions at the LME scale through multi-level governance policy cycles (Mahon et al 2009). A number of the immediate causes identified might be best addressed at the local level, with the necessary governance structures in place at this level.

Low priority is accorded to fisheries on the political agenda, owing to its low importance relative to other sectors such as tourism and industry. Stock assessment results and social and bio-economic information are rarely integrated into the policy-making process. An inherent problem is the existing focus on management of single stocks rather than on maintaining the overall health of the Caribbean Sea ecosystems, on which fisheries resources are dependent.

Unsustainable development models

Governments often formulate development agendas to alleviate poverty, stimulate economic growth and provide employment, rather than ensuring sustainable development. Fisheries expansion programmes have been undertaken in this manner, without adequate knowledge about the stocks and considerations of longterm sustainability. This is also related to the political cycle in the countries, with planning processes linked to short-term horizons.

Population and cultural pressures

Caribbean reef resources have been historically fished across the region, especially as the coastal areas are densely populated. Fish has historically been an important part of the diet of coastal communities, who depend heavily on reef fisheries as a source of food and livelihoods. In some countries, exploitation of certain reef associated species is a cultural tradition (e.g. exploitation of turtles by indigenous peoples in Central and South America). Growing demand for fish and fishery products, resulting from population growth, increasing purchasing power, and improved awareness of the nutritional value of fish, has resulted in excessive pressure on the region's fisheries resources. Increasing demand for employment by growing human populations will also put more pressures on reef resources due to limited opportunities in other sectors.

The relatively high poverty levels in some of the countries mean greater pressures on the fish stocks from people who have little alternatives for food and employment. Despite generally favourable social development rankings, poverty remains a concern across the region. The coastal zone is particularly important for the livelihoods of the poor, who exploit common pool resources such as fish (Brown et al 2007). The nearshore reef fish resources are an important part of the diet of local people and also provide considerable revenue, especially to poorer fishers lacking the means to exploit offshore pelagic resources.

Illiteracy, lack of other skills and unwillingness of some fishers to consider alternative employment and/or lack of other economic options continue to drive increased fishing pressure in some countries. High levels of unemployment in some areas force large numbers of persons to enter and remain in fisheries, which act as a safety net.

Inadequate knowledge and low public awareness

There is general poor understanding of environmental concepts and low public awareness about the importance of marine ecosystems in providing essential ecosystem services and the economic value of these services, particularly the non-tangible services. Fish catches are still seen as disconnected from the marine ecosystems from which they came and there is low awareness about the finite nature of living marine resources. This is changing in the region, however, with an upsurge in environmental education and awareness programmes. These are necessary to change perceptions and attitudes towards conservation and environmental responsibility.

Where scientific knowledge is available, it is often poorly communicated to, and understood by policy-makers and the public.

High dependence on fish for income and export earnings

Reef resources such as lobsters, conch, snappers and groupers are high value species; they dominate the CLME's total annual landings in terms of economic value. The CLME countries derive considerable economic benefits from fisheries, including in the form of foreign exchange. Reef fisheries resources are in high demand for export as well as by the tourism sector and local communities. Government policy in many countries is to expand fisheries as a means of generating jobs and foreign exchange, most often without adequate knowledge about the resources nor appropriate regulations and monitoring programmes.

Rising demand and increasing access to global markets promote heavy exploitation of the region's fisheries. According to FAO statistics fish exports from the CARICOM region amounted to around 200,000 tonnes, worth US$1.2 billion in 2000. Exports are dominated by high-value reef products such as spiny lobster, snappers, groupers, and queen conch, which command premium prices on the international market. Given the dependence of the region's fisheries sector on foreign markets where demand is strong and increasing, pressure on the region's stocks will continue to rise, especially as there have been large capital investment in fisheries. Greed also drives some individuals to engage in unsustainable practices to maximize their profits.

5.1.2. Habitat degradation and community modification

Sectors that contribute to degradation and community modification of reef habitats: All key sectors including fisheries, tourism, agriculture and aquaculture, forestry, urbanization, industry, construction, shipping, and energy production.

Immediate causes

The immediate causes of habitat and community modification of reef ecosystem are diverse with complicated interactions and synergies.

Physical alteration

Among the most important immediate causes of reef ecosystem degradation is mechanical (physical) damage from both anthropogenic and natural stressors. Physical damage to coral reefs could be attributed to a range of factors including coral collecting, destructive fishing gear and practices, and intensive use for tourism and recreation. Two direct impacts on Caribbean coral reefs are from vessel collisions and anchoring in fragile areas.

Coastal ecosystems can also suffer extensive physical damage from tropical storms and hurricanes. In recent years, the CLME region has been buffeted by a series of hurricanes, which left many reefs shattered, covered with sediment, and vulnerable to disease. Threats to mangroves and seagrass beds include coastal development, cutting for fuelwood and construction material, conversion (e.g. to shrimp farms, landfills, agriculture, ports and marinas, and residential and tourist developments), and prospecting for pharmaceuticals. Sandy foreshores have been severely destroyed and modified due to sand mining and poorly-devised shoreline protection structures. Degradation and loss of coastal habitats can have severe consequences for the adjacent habitat(s). For example, loss of mangroves can result in higher levels of pollution reaching adjacent coral reefs and seagrass beds, as well as in the loss of nursery areas for reef organisms. Alteration of the salinity regime of coastal areas through changes in natural flow of freshwater and increase in sea water intrusion through sea level rise cause disturbance of the delicate ecological balance necessary for the functioning of coastal habitats.

Harmful fishing practices such as indiscriminate use of heavy traps, poisons and explosives can cause severe damage to reef ecosystems. In recent years, commercial fishing on deep water reefs and slopes has caused extensive damage to these areas. While no significant threat of deepwater trawling has been reported for the WCR, shrimp trawlers have been exploring deep areas off Colombia. The impacts of trawling on the deepwater coral banks off Colombia need to be assessed (Reyes et al 2005). Oil and gas exploration and production, which are important activities in the region, can also cause physical damage to reef ecosystems.

Pollution

Two pollutants that have serious impacts on corals are nutrients and sediments. Burke et al (2011) reported that marine-based and watershed-based pollution each threatens about 25% of Caribbean reefs. Sewage is regarded as one of the most important and widespread causes of deterioration of the coastal environment in the Caribbean. Sewage, along with agricultural fertilizers, contributes excessive amounts of nutrients to coastal waters, resulting in eutrophication, harmful algal blooms, and hypoxia. Stimulation of the growth of algae and associated problems such as oxygen depletion could drastically alter the ecology of coral reefs, mangroves and seagrass beds.

High sediment load is one of the major threats to coastal reef habitats. Sediments can be carried long distances and affect coral reefs and seagrasses. Direct sedimentation can smother corals and seagrass beds and block sunlight, reducing photosysnthesis. There are many examples in the CLME where coastal habitats, especially coral reefs, have been degraded by high sediment loads.

Overfishing

In addition to direct damage to reefs from fishing practices (as described above), high fishing pressure and selective fishing can also alter community structure on reefs and associated systems, leading to ecosystem degradation. Burke et al. (2011) reported more than 70% of Caribbean reefs to be threatened by overfishing. Moreover, overfishing of herbivores such as parrotfish has caused drastic changes in Caribbean coral reefs, resulting in overgrowth of corals by algae. This has been exacerbated by pollution, principally elevated nutrient levels from sewage and agricultural fertilizers, which further stimulate the growth of algae. Many Caribbean reefs have experienced a shift in ecological dominance from corals to algae, with recovery rare and slow when it does take place. Selective fishing for top predators such as snappers and groupers has led to a reduction in the abundance of these groups and a shift towards dominance by species at lower trophic levels ("fishing down the food web"). Unsustainable fishing has also reduced populations of turtles throughout the region.

Invasive species

The Caribbean Sea has many potential vectors for the introduction of alien species. These include the Panama Canal and many active ports and international shipping that provide links for movement of species in ballast water or ship hulls. About 118 marine invasive species are known in the region. The invasive red lionfish is spreading rapidly throughout the Caribbean Sea and has the potential to drastically reduce the abundance of coral reef fishes and cause devastation of the reef ecosystem. Another well-known marine invasive species in the CLME region is the green mussel, which has already become established in many coastal areas, to the detriment of native species and associated fisheries.

Diseases

Coral reef diseases (such as white band, yellow band, dark spot, black band) are reported with increasing frequency in the Caribbean. Globally, the most reported observations of diseases affecting coral reefs have been in the Caribbean. White band disease has already decimated the prominent acroporid corals in the region. The spread of coral diseases has probably been facilitated by shipping and through increased transport of disease organisms in dust and continental river outflow. The occurrence of coral-reef diseases, such as *A. sydowii* may be partially due to pathogenic bacteria associated with an increasing intensity of Sahara dust over the last two decades. Coral that are already stressed by other factors such as bleaching are more susceptible to diseases.

Global warming and climate change

Climate change impact marine ecosystems through increasing SST (global warming) and increasing carbon dioxide concentration in seawater (acidification). SST trends for the Caribbean Sea show a 0.4 - 0.6°C increase from 1985-2006. Already there has been large-scale bleaching of coral reefs caused by increasing SST throughout the Caribbean Sea. In many areas, up to 100% of corals have been affected. This situation is expected to become worse in the future.

Coral and calcareous algae are also affected by ocean acidification, which make it harder for corals, clams, oysters, and other marine life to build their skeletons or shells. A number of recent studies demonstrate that ocean acidification is likely to harm coral reefs by slowing coral growth and dissolving calcareous skeletons, making reefs more vulnerable to erosion and storms. The frequency and intensity of storms and hurricanes are predicted to occur with rising temperatures. Reef ecosystems can suffer extensive physical damage from tropical storms and hurricanes, as already witnessed in the region. Changes in rainfall patterns and alteration of salinity regimes have the potential to cause extensive degradation of the region's reef habitats.

<u>Underlying Causes</u>

Demography and urbanization

The coastal areas of the CLME are heavily populated, with concentration of urban areas, towns and villages as well as industrial and tourism infrastructure along the coast. This is of particular importance in the Insular Caribbean countries, whose entire land mass could be considered coastal because of their relatively small size. In the Caribbean, about 43 million people live on the coast within 30 km of a coral reef[16]. The overall average urbanization rate of Latin America and the Caribbean is projected to reach 84% in 2015 (Smith 2010). The Insular Caribbean is expected to see an urban population increase of 4 million during the same period. Much of this urbanization occurs in coastal areas, and will intensify the pressures on the reef ecosystems.

Increasing demand for food production, employment, and income

Rising population will put more pressure on marine ecosystems as a result of increasing demand for living marine resources for food, construction material, as well as demand for employment and income (fisheries and tourism sectors). This will also extend to coastal and inland areas where increasing demand for food and housing for a growing population will see a rise in agriculture, mariculture, and other land use changes that could eventually affect marine ecosystems. Global demand for food is also rising, which drives an increase in the exploitation of living marine resources and in production of agricultural commodities for export. Unsustainable practices in these sectors result in degradation of marine habitats.

Land use changes and poor agricultural practices

Changes in land use in Caribbean watersheds have been the single greatest cause of coastal ecosystem damage. Nutrient and sediment pollution from agricultural areas is a severe problem in the WCR, impacting coastal and marine waters throughout the region. Burke and Maidens (2004) found that in more than 3,000 watersheds across the CLME region, 20% of coral reefs was at high threat and about 15% at medium threat from increased sediment and pollution loads from agricultural lands and other land modification. Deforestation especially on hillsides and general poor agricultural and aquaculture practices all contribute damaging sediment and pollution to coastal waters. Fertilizer, agro-chemical, and manure runoff from agricultural lands in upstream coastal areas of WCR countries are significant sources of nutrients and other agrochemicals to the marine environment from non-point sources. These contaminants are particularly prevalent because important crops like sugar cane, citrus fruits, bananas, grains and coffee require large amounts of fertilizers and pesticides. CLME countries used more than 1.7 million tonnes of fertilizers in 2005 (UNEP-RCU/CEP 2010). Annual fertilizer use by countries/territories is given in Annex 8. In general, there is a low level of implementation of sustainable agricultural and industrial practices. Land use changes and water diversion also affect the natural flow of freshwater to coastal areas, disturbing the salinity regime that is needed for the survival of mangroves and seagrass beds. For example, the construction of a highway in the Magdalena delta/lagoon complex of Colombia has resulted in diversion of water and hypersalinization of mangrove soils, and consequent die-off of mangroves.

[16] Burke et al 2011. Calculated at WRI based on data from LandScan High Resolution Global Population Data Set, Oak Ridge National Laboratory, 2007 and coral reef data from the Institute for Marine Remote Sensing, University of South Florida (IMaRS/USF), Institut de Recherche pour le Développement (IRD), UNEP-WCMC, The World Fish Center, and WRI, 2011.

Poorly planned coastal development

There is growing investment and development in coastal areas, much of which is tourism-related. Coastal development threatens at least one quarter of Caribbean reefs (Burke et al 2011). Coral reefs, mangrove swamps, and seagrass beds are declining in extent due to development-related activities that target flat land on the coast or land reclaimed from the sea. Increasing tourism and urbanization is a dominant feature throughout the region, particularly in coastal areas that are also the focus of increasing industrial development. Land reclamation, industrial and harbour installations, dredging or extraction of sediments, disposal of wastes and dredged material, recreational activities, military activities and aquaculture operations all tend to concentrate along the coast. In some countries tourism development has occurred at the expense of seagrass beds and mangroves. Other threats to seagrass beds in the Caribbean are removal from shallow water to "improve" bathing beaches; dredging for creation of shipping channels or to lay cables, pipes, and other submarine structures. Extensive clearing of mangroves for settlement, agriculture and shrimp ponds are among the major causes of mangrove decline in the region.

Harmful tourism practices

Tourism can have both direct and indirect impacts on coastal habitats. Activities with direct physical impacts include snorkeling, diving, reef walking, turtle watching, boating, fishing and collecting, which can cause physical damage and contribute to over-exploitation of reef species and threaten local survival of endangered species. Indirect impacts relate to the development, construction, and operation of tourism infrastructure as a whole (resorts, marinas, ports, airports, etc.). Tourism-related sources of sewage pollution include hotels, resorts and recreational vessels. The Caribbean is the world's major cruise destination, with 14.5 million cruise passengers visiting Caribbean ports in 2000 (Ocean Conservancy 2002, CTO 2002). During the period 1990-2000 the industry has grown annually by 6.5% (CTO 2002). The cruise ship industry contributes a number of stressors (e.g. pollution from liquid and solid waste, vessel groundings), although efforts are being made to reduce the environmental impacts. Tourism is the fastest growing sector, which can see an increase in its impacts if appropriate measures are not taken.

Limited integrated watershed and coastal area management

Influences from watersheds have severe impacts on reef habitats throughout the region. Although initiatives are underway to develop IWCAM, this is not effectively implemented in all the countries and is not yet mainstreamed into development planning at national and regional levels. The sectoral approach to development is still the norm. Much of the region has no coastal zoning or coordinated inter-sectoral land-use planning to ensure sustainability, so development is haphazard and loosely controlled. Regional policies that promote the development of river basin, coastal and marine planning and management are generally absent and appropriate legislation and institutional capacities are weak.

Limited capacity for implementation and enforcement of habitat conservation measures

At present, there appears to be a mismatch between the technical and managerial capabilities of authorities in the region, and the scale of important transboundary problems related to overfishing, habitat destruction, pollution, unsustainable agriculture, and tourism. There is limited institutional and human capacity for implementation of measures to conserve Caribbean marine habitats and for enforcement of these measures at the local, national, and regional scales. This is demonstrated in the poor implementation and enforcement of the existing regional and international policy frameworks (e.g. SPAW Protocol, CBD) and of measures such as MPAs and no-take reserves. Only about 14% of the region's MPAs are partially or fully managed effectively. Lack of or poor enforcement continues to be a driver for unsustainable practices. Marine science and technology capacity, as well as the capacity of local communities to participate in conservation programes, is also inadequate in the region. Further, given the wide diversity in size and economic development among Caribbean countries, the capacity to participate in collective mechanisms will vary considerably (CARSEA 2007). Limited financial resources for implementation and enforcement of sustainable practices and low capital investment by both public and private sectors in these practices further compound the problem of habitat degradation in the region.

Inadequate data and information

Although there is an enormous body of data and information on Caribbean reef and other coastal habitats, important gaps persist. These include information on the degree of connectivity between adjacent habitats in specific areas and quantitative information on the functional role of reef habitats and on the impacts of habitat degradation on transboundary living marine resources as well as of the impacts of human activities (both coastal and land-based) and natural stressors on the productivity and carrying capacity of reef ecosystems. Existing data and information at the regional level are still very scattered and fragmented, and there is need for greater harmonization and integration of data and information to effectively manage the shared living resources of the CLME.

Harmful subsidies and lack of incentives for sustainable practices

These include harmful agricultural subsidies, and lack of or limited incentives for sustainable practices in agriculture, tourism and other sectors. Substantial subsidies are provided for the purchase of agricultural fertilizers in some countries. There is also low awareness about sustainable practices in all sectors, although this is slowly changing.

Intensive maritime and petroleum activities

The Caribbean Sea is intensively used for shipping and petroleum exploration, extraction, refining, and transport. These activities can result in degradation of marine areas through pollution from hydrocarbons and other hazardous substances as well as through mechanical damage/loss of critical habitats. In addition, the high shipping traffic in the Caribbean Sea poses a significant potential danger from the introduction of marine invasive species. This underlying cause is discussed further in the Pollution CCA.

Inadequate waste management

Inadequate waste management and disposal result in pollution of coastal areas when waste is disposed at sea and through runoff from terrestrial areas. See Pollution CCA.

Root causes

Some of the socio-economic, legal, and political root causes of habitat degradation and community modification of the pelagic ecosystem are similar to those of unsustainable exploitation (Poor governance, unsustainable development models, population and cultural pressures, high dependence on living marine resources for livelihoods, income and export earnings).

Poor governance

Efforts to protect marine ecosystems and resources have been fragmented and largely inadequate. For example, in the MAR countries, Belize has 2% of its marine territory in fully protected zones, followed by Mexico and Honduras with less than 1%, and none in Guatemala. Where protected areas exist, surveillance and enforcement are usually limited or non-existent. There is poor integration of environmental considerations into development planning in the region. Further, the management of the Caribbean Sea is characterized by uncoordinated efforts without any holistic integrated management plan. Management is organized primarily at the level of individual countries or political blocs, while what is required is to deal with marine environmental problems of the CLME at the scale of the entire ecosystem. As previously mentioned, transboundary living marine resources require coordinated and harmonized governance structures and policy cycles at local, national, sub-regional, regional, and where appropriate, global scales, with appropriate linkages between them. A number of the immediate causes identified might be best addressed at the local level, with the necessary governance structures in place at this level.

The environment is given low priority on political agendas and over short-term economic development. Stakeholder involvement in the management of marine habitats and living resources is still relatively low, although there are many examples of this in the region.

See Fisheries CCA for other elements associated with poor governance.

Weak and ineffective legal and institutional frameworks

At the national level, legal and institutional frameworks are often weak and ineffective, due to a number of factors including fragmentation of responsibilities among various departments and limited coordination among them, limited cross-sectoral approaches in development panning, and inadequate human and financial resources. Where measures are in place to conserve reef habitats (e.g. MPAs), there is often limited surveillance and enforcement. The relevant MEAs such as the SPAW Protocol, CBD, CCD, RAMSAR, etc. are still to be ratified by many of the Caribbean countries. The SPAW protocol has been ratified so far by only 13 Caribbean States (Annex 9). Moreover, in countries that have already ratified these MEAs, there is often poor implementation and enforcement at the national level. There are inadequate unified and harmonized frameworks for transboundary habitat issues at the regional level.

Trade and external dependency

The high dependence on international tourism and agricultural exports and in some cases limited opportunities for economic development in the countries (especially in the Insular Caribbean countries that have a very narrow natural resource base and opportunities for diversification) causes intense pressures on the region's living marine resources and environment. Capital investment in Caribbean tourism is the highest in the world relative to its size, with a proportional demand for coastal infrastructure at the expense of coastal ecosystems.

Lack of economic valuation of ecosystems and their services

Apart from the value of tangible services such as fish catch, the economic value of ecosystems and their services is largely unknown and go unrecognized and unaccounted for. Past attempts to estimate the value of ecosystem services provided by Caribbean coastal habitats have focused on coral reefs in a few countries (Burke and Maidens 2004, Burke et al 2008, Cooper et al 2009, Wielgus et al 2010), which included mangroves in Belize (Cooper et al 2009). Similarly, the economic cost of habitat degradation in the Caribbean has been estimated only for coral reefs (Burke and Maidens 2004). Mangroves and seagrass beds are often seen as wasteland to be reclaimed or used for disposal of waste. Until the soco-economic value of reef ecosystem services is recognized and accounted for in national development planning, reef and associated habitats will continue to be degraded.

Limited knowledge and public awareness

There is often limited knowledge, public awareness, and appreciation including about the importance of marine ecosystems and their services to food security and socio-economic development in the region, and of humans as an integral component of the CLME as well as of the vulnerability of these ecosystems. There is also low awareness about sustainable practices in all sectors that impact on reef ecosystems. Furthermore, there is limited awareness about the shared nature of the Caribbean Sea and of the connectivity among its habitats and living resources. Wider Caribbean states have not grasped the possibilities under the various policy instruments for forging the kind of sub-regional and regional co-operation required for better management of the Caribbean Sea and its resources (CARSEA 2007). This situation is changing, however, with increasing educational and public awareness programmes in the region.

Population and cultural pressures

Increasing human population throughout the region is accompanied by rising demand for living marine resources as a source of food, income and employment, which will intensify the pressures on reef ecosystems. Higher populations also mean greater demand for food crops and livestock and associated requirements for agricultural land, for housing and infrastructure, and other services that could increase the pressures on coastal habitats (e.g. from land-based pollution). The relatively high poverty levels in some of the countries mean greater pressures on coastal habitats from people who have little alternatives for food and employment. This is compounded by illiteracy among the poorer communities. Many poor communities also engage in agriculture and livestock farming, which could contribute to degradation of coastal habitats (e.g. from excessive sediments and nutrients).

5.1.3. Pollution

Sectors that contribute to pollution of coastal and marine areas in the Caribbean: All key sectors including fisheries, tourism, agriculture and aquaculture, urbanization, industry, shipping, transport/infrastructure, and petroleum exploration, extraction, refining, and transport.

The principal immediate causes of pollution of the reef ecosystem include a wide range of substances, of which nutrients and sediments have been observed to have caused the greatest damage to coral reef ecosystem in the CLME. Marine and coastal areas are also at significant risk from hydrocarbons, which can also cause severe damage to reef ecosystems. The CCA for reef ecosystem will focus on nutrients, sediments, and hydrocarbons. These are also discussed in the pelagic ecosystem CCA along with other pollutants.

Immediate causes

Nutrients

High nutrient loads (nitrogen and phosphorus) in coastal areas arise mainly from sewage outflow and agriculture and aquaculture runoff, which increase during periods of heavy rainfall. Unauthorized discharge of sewage from ships, including cruise ships and recreational boats, also contributes to this problem. The total estimated nutrient load to the Caribbean Sea has been estimated at 722,000 tonnes per year of total nitrogen and 136,000 tonnes per year of total phosphorus (UNEP-RCU/CEP 2010). Excessive nutrient inputs cause eutrophication of coastal waters, which can result in algal overgrowth of coral reefs, harmful algal blooms, hypoxia and fish kills. High inputs of untreated or partially treated sewage into coastal areas, along with other contaminants, are responsible for a number of coastal hotspots in the region.

Sediments

Considerable quantities of suspended sediment are introduced by rivers and watercourses to the coastal areas of the CLME. Rivers from both within and outside the Caribbean region deposit enormous quantities of sediments in coastal waters annually. The Magdalena River in northern Colombia, which has the highest freshwater discharge of all Caribbean rivers, contributes an estimated 144 tonnes/yr. Significant quantities of freshwater and sediments also come from rivers outside of the CLME (Amazon and Orinoco Rivers). Annual sediment input to the CLME region has been estimated at about 216 million tonnes (excluding inputs from the Orinoco due to insufficient data) (UNEP-RCU/CEP 2010). In addition to increasing water turbidity (which by itself has negative impacts on reef ecosystems by blocking light and causing mechanical damage by scouring), sediments can smother reefs and sediment particles may carry pollutants such as heavy metals and pesticide residues as well as microbes, which are harmful to marine organisms and to humans. In recent years suspended sediment loads to the Caribbean Sea have increased substantially as a result of poor land use practices and land use changes, land degradation and soil erosion. High suspended sediment levels also arise from dredging in harbours and from coastal erosion. This has increased the turbidity of coastal waters, with potentially severe impacts on reef ecosystems.

Hydrocarbons

Oil spills associated with industry, shipping, and offshore operations constitute one of the greatest environmental threats to the WCR. In general, the major concern of contamination from petroleum hydrocarbons in the Caribbean region is from accidental events, such as large oil spills, although there is evidence of chronic hydrocarbon pollution in some areas. Oil and its refined products are a complex mixture of substances, of which could be highly toxic to marine organisms. Dispersants used in oil spills and derivate substances may be toxic at low concentrations to marine organisms. Although of great concern, long-term effects of hydrocarbons in the ocean are generally limited, oil spills in the WCR have adverse effects on the ecology of coastal ecosystems, particularly coral reefs, marine feeding grounds, mangroves, seagrass beds, fish, turtles and shellfish populations. Large spills can have devastating short-term lethal and sub-lethal consequences for local flora and fauna.

Underlying causes

The underlying causes of pollution are the same as for habitat degradation (improper land use and poor agricultural practices, unsustainable tourism practices, poorly planned coastal development, increasing demand for food crops and other products for local consumption and export including from aquaculture).

Demography and urbanization

The coastal areas of the CLME are heavily populated, with concentration of urban areas, towns and villages as well as industrial and tourism infrastructure along the coast. This is of particular importance in the Insular Caribbean countries, whose entire land mass could be considered coastal because of their relatively small size. The overall average urbanization rate of Latin America and the Caribbean is projected to reach 84% in 2015. Much of this urbanization occurs in coastal areas, which will place lead to increased pollution of the marine environment if adequate measures are not implemented to address pollution.

Inadequate waste management and disposal

Inadequate waste management and disposal result in pollution of coastal areas when waste is disposed at sea and through runoff from terrestrial areas. Countries have limited capacity for proper treatment and disposal of both domestic and industrial waste. The pattern of sanitation coverage in the region is extremely patchy in terms of its extent and treatment capabilities (Cimab 2010). In WCR countries, an important sector of the population lives in coastal areas where sewerage systems are deficient and even absent in some cases (Cimab 2010). Moreover, in countries that have sewer systems a shortage of sewage treatment plants or non-functioning plants is common. In the WCR, the average (unweighted) proportion of sewage that is treated is about 44% (UNEP-RCU/CAR 2010). There are about 58 submarine outfalls in the region (39 of which are in Venezuela)[17].

Proper management and disposal of industrial waste is also limited, including treatment of point sources of discharge and construction and maintenance of storage facilities for industrial waste. There have been some recycling programmes established in the region, but these need to be increased. The adoption of cleaner production technologies in industry has historically been inadequate, but this is slowly changing. There has been an increase in the industrial wastewater treatment capacities and disposal, in particular in the oil industry and the increase of the environmental awareness. Also, governments have increased demands on industry as regards environmental protection in the WCR in the recent years (UNEP-RCU/CAR 2010).

Improper land use and poor agricultural practices

Changes in land use in watersheds in the Caribbean have been the single greatest cause of coastal ecosystem damage. Deforestation especially on hillsides and general poor agricultural and aquaculture practices all contribute sediment and pollution from fertilizers, pesticides, and other toxic substances to coastal waters. Fertilizer, agro-chemical, and manure runoff from agricultural lands in upstream coastal areas of WCR countries are significant sources of nutrients and other agrochemicals to the marine environment from non-point sources. These contaminants are particularly prevalent because important crops like sugar cane, citrus fruits, bananas, grains and coffee require large amounts of fertilizers and pesticides. CLME countries used more than 1.7 million tonnes of fertilizers in 2005 (UNEP-RCU/CEP 2011). The application of pesticides in seven countries (Colombia, Costa Rica, Dominican Republic, Honduras, Jamaica, Nicaragua and Panama) has been estimated at 76,000 tonnes between 1995 and 2001 (UNEP-RCU/CEP 2010). In general, there is a low level of implementation of sustainable agricultural practices.

Increasing demand for food production, employment, and income

Rising population will put more pressure on marine ecosystems as a result of increasing demand for living marine resources for food, construction material, as well as demand for employment and income (fisheries and tourism sectors). This will also extend to coastal and inland areas where increasing demand for food and housing for a growing population will see a rise in agriculture, mariculture, and other land use changes that could eventually affect marine ecosystems.

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[17] Based on national reports prepared for the Updated CEP Technical Report 33; and Salas, H. 2000. Emisarios submarinos. Alternativa viable para la disposición de aguas negras de ciudades costeras en América Latina y el Caribe. OPS/CEPIS/PUB/00.51.

Global demand for food is also rising, which drives an increase in the exploitation of living marine resources and in production of agricultural commodities for export. Unsustainable practices in these sectors result in degradation of marine habitats.

Poorly planned coastal development

There is growing investment and development in coastal areas, much of which is tourism-related. Land reclamation, industrial and harbour installations, dredging or extraction of sediments, disposal of wastes and dredged material, recreational activities, military activities and aquaculture operations all tend to concentrate along the coast. Pressures associated with coastal development include habitat alteration, discharge of sewage and other pollutants, urban runoff, and increased sediment loads and solid wastes, which cause degradation of the pelagic ecosystem.

Harmful tourism practices

Tourism can have both direct and indirect impacts on reef habitats, including from disposal of waste and oil spills. Tourism-related sources of sewage pollution include hotels and resorts and, to a lesser extent, recreational vessels. The Caribbean is the world's major cruise destination, with 14.5 million cruise passengers visiting Caribbean ports in 2000 (Ocean Conservancy 2002, CTO 2002). During the period 1990-2000 the industry has grown annually by 6.5% (CTO 2002). The cruise ship industry contributes to a number of stressors (e.g. pollution from liquid and solid waste, vessel groundings), although efforts are being made to reduce the environmental impacts. Tourism is the fastest growing sector, which can see an increase in its impacts if appropriate measures are not taken.

Intensive maritime and petroleum activities

The Caribbean Sea is intensively used for shipping and petroleum exploration, extraction, refining, and transport. These activities present a high risk of pollution in the region, which is likely to increase with increasing ship traffic and oil exploitation including in offshore areas. The main causes of elevated hydrocarbon concentrations in the region are leaching of drilling oils and other residues from the oil industry, vandalism, shipping traffic discharges (mainly bilge oil and fuel oil sludge), and accidents (INVEMAR 2007, PNUMA 2007).

High shipping traffic in the Caribbean Sea poses a significant potential danger from oil spills and other hazardous substances, as well as from ballast water. During the period 2003-2004, ship traffic in the Caribbean Sea was estimated as an average of 8,664 ships per month and 285 ships per day, much of this associated with the Panama Canal. In 2005, six million tonnes of ballast water were poured into the Caribbean Sea, of which 84% came from international shipping. About 7 million barrels of oil are discharged annually from ship tank washings.

Root causes

Poor governance

Efforts to protect marine ecosystems and resources have been fragmented and largely insignificant. There is poor integration of environmental considerations into development planning in the region. Further, the management of the Caribbean Sea is characterized by uncoordinated efforts without any holistic integrated management plan. Management is organized primarily at the level of individual countries or political blocs, while what is required is to deal with marine environmental problems of the CLME at the scale of the entire ecosystem (CARSEA 2007). As previously mentioned, transboundary living marine resources require coordinated and harmonized governance structures and policy cycles at local, national, sub-regional, regional, and where appropriate, global scales, with appropriate linkages between them. A number of the immediate causes identified might be best addressed at the local level, with the necessary governance structures in place at this level.

The environment is given low priority on political agendas and over short-term economic development. There is limited investment in pollution control and waste treatment facilities. Stakeholder involvement in the management of marine habitats and living resources is still relatively low, although there are many examples of successful stakeholder involvement in the region. Despite the existence of regional and international policy frameworks related to pollution, a harmonized governance mechanism at the regional level to address transboundary pollution is lacking. A number of the following causes are also related to governance.

Weak and ineffective legal and institutional frameworks and poor enforcement

At the national level, legal and institutional frameworks to address pollution are often weak and ineffective, despite the existence of a number of relevant laws and regulations related to pollution. The relevant MEAs such as the LBA and Oil Spill Protocols, MARPOL, and Ballast Water Convention are still to be ratified by many of the Caribbean countries. Table 18 shows the number of countries that have ratified/acceded to the Cartagena Convention and the LBA and Oil Spill Protocols. Moreover, in countries that have already ratified these MEAs, there is often poor implementation, compliance, and enforcement at the national level. Monitoring and enforcement of the implementation of these MEAs are the responsibility of national governments, which often lack the capacity and the political will to fulfill their obligations.

Inadequate environmental quality standards and legislation

Most of the WCR countries do not possess national environmental quality norms for coastal areas or in other cases they exist but are incomplete (UNEP-RCU/CEP/Cimab 2010). Where these exist, there is often poor compliance, monitoring and enforcement. National programmes do not usually address regional concerns and focus on addressing domestic impacts, rather than those occurring outside of territorial limits or in international waters.

Inadequate data and information

Because of limited financial and human resources and other factors, pollution monitoring, control, and assessment activities are weak and inadequate. While numerous studies have been conducted in localized areas, most are sporadic and limited in scope. There are no systematic regional monitoring and data sharing programmes (apart from the monitoring of dust) that specifically focus on transboundary pollution and its impacts. Moreover, methodologies are often not standardized and harmonized, even the national level, which makes it difficult to compare status and trends. In general the quality of regional environmental data is low, as few countries have the necessary systems in place to collect quality-assured environmental data on a regular basis. This is being addressed however, as demonstrated by recent reports on pollution from UNEP-RCU/Car and Cimab. These studies have pointed out a number of data and information gaps both with respect to particular substances and coverage among the countries. Collection of data and information on the impacts of pollution on marine habitats and their living resources, as well as socio-economic impacts and costs need to be improved.

Limited financial and human resources

Many of the CLME countries lack the necessary financial resources for construction and/or maintenance of sewage treatment plants and industrial and other waste treatment infrastructure. Inadequate financial and human resources also contribute to inadequate monitoring, surveillance, and pollution assessment activities. Attempts to implement the 'polluter pays' principle can be fraught with considerable difficulties.

Low awareness of the value of the environment

The sea is generally seen as a receptacle for waste, with unlimited capacity to absorb the wide range of substances and materials that are disposed in coastal and marine areas. It is a common practice in the region's coastal towns to discharge domestic wastewater (treated or otherwise) into the nearest or most convenient body of water, in many cases because of lack of knowledge and indifference to the damage this causes to the environment and to public health. Awareness of the socio-economic and ecological value of marine and habitats and living marine resources is limited.

In general, there low public awareness about the relationship between development and environmental protection, and between overall ecosystem health and the production of ecosystem services. This contributes to the low priority given to the environment on the political agenda.

5.2. Pelagic Ecosystem Causal Chain Analysis

The CCA for the pelagic system is very similar to that of the reef ecosystem. In many cases, data and information were not available in a disaggregated for for these two systems separately. The information from the reef CCA is repeated where necessary in the pelagic ecosystem CCA.

5.2.1. Unsustainable exploitation

Sectors that contribute to unsustainable exploitation: Fisheries; tourism; coastal urbanization (high demand for employment and seafood, recreational fishing)

Immediate causes

Catches beyond sustainable levels, including immature and/or spawning individuals

Humans can negatively affect pelagic fish stocks directly when catches are so large (beyond MSY) that the remaining population (spawning stock biomass) is insufficient to replenish the population. Catches of a number of large coastal and oceanic pelagic species in the CLME have declined in the last few years despite increasing fishing effort, a clear sign of unsustainable exploitation. Assessment of large pelagic species by ICCAT has suggested that some of these HMS & SS are already considered to be overfished throughout the Atlantic. Unsustainable fishing has also affected the biodiversity of Caribbean marine mammals, seven species of which are classified as endangered or vulnerable by the IUCN. Of the two pinnipeds, the West Indian monk seal is generally considered extinct and the population of the West Indian manatee has been significantly reduced through excessive hunting.

The large pelagic species, including wahoo, experienced progressive reductions in mean CPUE during the 3 years. This was attributed to the redirection of fishing from reef to pelagic species when the former were fished out, and an enormous increase in the number of fishers as well as the catching of juveniles (about 18% of wahoo caught were juveniles).

Bycatch and discards

Gillnets and longlines used to capture pelagic fish result in considerable bycatch of non-target species that are themselves targeted in other fisheries, or are endangered and vulnerable. Among these are small tunas, sharks, marine mammals, turtles and seabirds. Bycatch poses a threat to the biodiversity of non-target species. The blue shark is one of the most common species in tuna longline bycatch in the region. This species is listed in the IUCN Red List as Near Threatened, with decreasing population trend. Similarly, all members of the genus *Alopias* (thresher sharks) are listed as Vulnerable globally because of their declining populations. These downward trends are the result of a combination of slow life history characteristics (hence low capacity to recover from moderate levels of exploitation), and high levels of largely unmanaged and unreported mortality in target and bycatch fisheries. Estimates of the quantity of bycatch in a number of countries are given in Table 17. These estimates are not disaggregated for reef and pelagic resources, but show the considerable quantities of bcatch and discards form these countries.

Underlying causes

Open access nature of fisheries

Caribbean fisheries are largely open access - anyone can enter the fishery and there are no set limits on the number of fishers (although unprofitable catches could eventually force fishers out or discourage others from entering). The ease and low cost of catching reef fish also makes them more susceptible to heavy fishing pressure. This is exacerbated by the limited employment opportunities in other sectors. ICCAT establishes measures such as quotas for pelagic fisheries. However, regulations to limit effort or allocate catches, where they exist, are usually not adequately enforced. Illegal fishing by foreign fleets in the Caribbean Sea also contributes to excessive pressure on the fisheries stocks. This is difficult to control because of the lack of a regional governance framework for transboundary fisheries and insufficient capacity of the countries for monitoring and surveillance of their respective EEZs.

Fishing overcapacity

Historically, under open access conditions, fishing fleets have expanded far beyond the size needed to economically catch the available fishery resources. In the 1950s and the 1960s several Caribbean countries undertook major fishing capacity expansion, fleet mechanization and acquisition of advanced technology and fishing gear. In the 1970s, especially after the declaration of the EEZ regime, a number of countries also expanded their offshore fleet capacities for large pelagic species. These expansion programmes resulted in fishing effort accumulation in major fishing grounds. Currently, significant numbers of medium and large longliners operate in the region. Fisheries regulations have not prevented the depletion of fishery resources. Related to the over-capitalization of fisheries is the cryptic mortality exerted by lost gear (ghost gear) such as gillnets and longlines. Fisheries expansion has had considerable impacts throughout the region. Declines in CPUE, reduction in the size of fish caught and changes in species composition are evident in the region's large pelagic fisheries. Despite declining CPUE, fishing fleets continued expanding throughout the 1990s in the region. This has led to overcapitalization of the fisheries and reduction in the fisheries stocks.

Calculation of catch-and-effort trends in four of the Windward Islands showed that fish catches by these fleets failed to keep pace with a the dramatic expansion of fishing effort in the last two decades of the 20th Century, especially in offshore waters.

Destructive fishing methods

All fishing methods have an impact on the target resource and may also affect non-target species and the wider marine environment. These practices could be categorized as:

- Destructive fishing practice, or destructive use, e.g., when a gear is used in the wrong habitat, such as bottom trawls in seagrass, macro algae or coral beds; and
- Destructive methods, the impact of which are so indiscriminate and/or irreversible that they are universally considered "destructive" in any circumstances.

Here, the focus is on the second category (the first is discussed in the habitats CCA). Destructive fishing methods include gillnets and longlines used to capture pelagic fish, which result in considerable bycatch of undersized fish of the target species, as well as of non-target species that are themselves targeted in other fisheries (including billfishes that are important in recreational fisheries), or are endangered and vulnerable. Beach and purse seining used to catch pelagic species also capture large quantities of bycatch, including juvenile fish. Panama has recently become the first Central American country to ban pelagic longline gear within its waters, after banning commercial purse seining from its waters.

Illegal, Unregulated, and Unreported catches

IUU fishing contributes to overexploitation of fish stocks and hinders the recovery of fish populations and ecosystems. Because of the open access and unregulated nature of most Caribbean pelagic fisheries, much of the catches are likely to be unreported, especially for the artisanal sector. As a consequence, these catches are seldom registered and are not invisible in the national or local economy, which makes it difficult to develop adequate policies and management plans for sustainable fisheries or to improve surveillance and enforcement. Agnew et al (2009) estimated that between 2000 and 2003, the magnitude of illegal and unreported catch of tunas for the Western Central Atlantic was about 10% that of reported landings. The worst period for illegal and unreported fishing worldwide appears to have been the mid-1990s, driven by a combination of a growing world demand for fish and significant overcapacity of the world's fishing fleet set against increasing limitation of access to distant water fishing nations and a lack of new or alternative fishing opportunities. Limited capacity by the countries for surveillance and monitoring of fishing activities, especially for offshore pelagic fisheries, contributes to this problem. The issue of Flags of Convenience also promotes IUU fishing in the region and high seas.

Deficiencies in institutional, policy, and legal framework

The policy framework and institutional capacity to manage fisheries at the national and regional levels for the management of shared stocks is inadequate in the CLME. Participation of the countries in collaborative management of transboundary resources is generally low due to the absence of a regional mechanism to manage shared fisheries resources. There is a general lack of harmonized regulations for the transboundary fisheries at local, national and regional levels.

While most of the countries have legislation related to the exploitation and management of living marine resources, few have provisions specifically related to large pelagic species. Existing fisheries regulations are not efficiently applied and poorly enforced. There is a chaotic policy in allocating access rights, and where such policies exist, there is often the tendency to distribute more fishing licenses and permits than required to achieve the allocated catches. Pelagic fisheries management initiatives are partly governed by international frameworks such as the UN Law of the Sea Convention relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish

Stocks, CITES, and FAO Code of Conduct for Responsible Fishing. The best established and operational large pelagic fisheries management organization with relevance to the Caribbean Sea LME is ICCAT, which has the mandate to manage all tuna and tuna-like species in the Atlantic. Currently, however, only three Insular Caribbean countries (Barbados, Trinidad and Tobago, St. Vincent and the Grenadines) and six continental countries (Belize, Guatemala, Honduras, Panama, Mexico, and Venezuela) are contracting parties to ICCAT. Colombia has been granted the status of ICCAT Cooperator. The regional flyingfish fisheries continue to operate essentially unmanaged and are poorly monitored, and growth in flyingfish catch is taking place in completely unmonitored bait fisheries (Fanning and Oxenford in press).

Limited institutional, human, and technical capacity

Government institutions have limited capacity to mitigate the adverse effects of development on coastal areas or to resolve conflicts over the allocation of common resources. Important elements lacking or limited in most countries are: leadership and continuity; trained staff; inter-agency coordination, including formal mechanisms for resolving resource conflicts; fully participatory processes; and an ability to enforce regulations. The capacities of fisheries departments are limited with respect to personnel, equipment, and training. Some countries have experimented with restructuring to overcome institutional problems such as inter-agency commissions or semi-autonomous units. But without real improvements in capacity accompanied by mechanisms to ensure the financial sustainability of fisheries management, institutional restructuring has had limited effect on how these resources are managed

Ineffective enforcement, monitoring, and surveillance

In general, legislation at national and local scales exists in the countries, but the lack of or poor enforcement is a driver for unsustainable practices. The virtual lack of maritime surveillance and enforcement, particularly in remote coastal and offshore areas, is a widespread institutional problem that has left several locations vulnerable to illegal activities. Non-compliance with fisheries regulations by foreign fleets, due to inadequate monitoring and surveillance, is also of concern in the region. Limited financial resources and human capacity for fisheries assessment and management result in non-existent or limited monitoring, surveillance and enforcement of existing national policy and legislation, and limited implementation of the relevant MEAs. Existing national fisheries regulations are not efficiently applied and enforced.

Inadequate financial resources

Caribbean countries often lack the required financial resources for fish stock assessment, management, surveillance and enforcement. Fisheries resources are freely available, common property and innovative approaches are required to ensure that adequate funds are available for effective management of the region’s resources. Among such approaches is payment for ecosystem services, which is still in its infancy in the region. Despite limited financial resources, Governments commonly provide enormous subsidies that are harmful to the very resources that form the basis of the targeted programmes.

Perverse incentives

Perverse incentives (e.g. harmful fishing subsidies) have been a major reason for overexpansion of the fishing fleet. Huge subsidization programmes in the 1970s, involving loans for vessels, gear purchases and fuel tax rebates, were implemented in several Caribbean islands (Mohammed 2003). This has helped to increase fishing effort and promote fishing overcapacity for pelagic fisheries. Estimates of good and bad fishing subsidies in CLME countries are given in Annex 7. Bad subsidies are far outweighed by incentives for sustainable fisheries (good subsidies). The total value of (non-fuel) bad subsidies (e.g. for boat building) in 21 CLME countries was estimated in 2000 at about US$252 million, which was five times greater than the value (about US$49.5 million) of good subsidies (e.g. for management and surveillance) (Sumaila and Pauly 2006). Perverse incentives continue to exist throughout the region, and include fuel rebates and tax concessions on fishing equipment.

Improvements in technology

Improvements in technology (e.g. more efficient vessels and gear, modern fish-finding equipment and navigation systems) serve to increase pressures on fish stocks, especially those in previously inaccessible offshore areas. During the fisheries expansion in many of the CLME countries in the 1970s and 1980s, not only were larger vessels acquired, but also advanced technology that help with navigation, fish finding and catching, and cold storage of the catch on board that allowed vessels to remain longer on the fishing grounds, among other benefits. Fishing vessels such as longliners that target the large pelagic resources are well equipped with modern gear, etc. In the CLME region, government subsidies have promoted the acquisition of advanced technology, much of which is concentrated in the large pelagic sector.

Inadequate data and information

Considerable data and information gaps still exist, particularly with respect to the transboundary fisheries resources. For widely distributed and migratory stocks, data are needed from across their entire geographical range. Catches are seldom reported, and when they are, there are questions about their reliability or a large proportion is not identified to species level. There is a high degree of uncertainty in the spatial oceanic dynamics of migratory species, and there is a need for standardized indices of abundance, sustainable yield, and fishing effort for these resources. Significant gaps still exist on the biology and population dynamics of individual species. Inadequate or unreliable data introduces high uncertainty about the status of even the most important fish stocks. Inadequate data is often cited (e.g. by CRFM and ICCAT) as a serious limitation in stock assessments of pelagic fisheries. This issue also prevents the development of effective and harmonized fisheries management measures for transboundary resources.

Despite a number of data collection and fish stock assessments in the region and the obligation of countries to report their catches to FAO and ICCAT, significant gaps persist in data and information required for effective management of the CLME's transboundary fisheries resources. There is an absence of centralized and coordinated regional database and limited national databases. Language and cultural barriers can often constrain the sharing of data and information at the sub-regional and regional levels. Unless urgent steps are taken to collect sufficient data to ensure that resources are used responsibly, there is a high risk that landings will continue to decline. The move towards more integrated, holistic approaches to living marine resources management has revealed major gaps in the knowledge required to implement these approaches.

Root causes

Poor governance

Poor or inadequate governance is often cited as one of the root causes of fisheries overexploitation. Efforts have been made to protect and preserve the coastal and marine resources of the Caribbean Sea through a number of regional and international conventions and subsequent legislative frameworks. However, at the national level, the administration of the relevant legislation (where it exists) is often scattered across several governmental agencies with weak institutional provisions for the coordination of environmental initiatives across the various sectors. In most countries, stakeholder consultation and participation in governance remain fragmented and weak, despite efforts to address this problem and recognition of its potential role in effecting new and more successful ways of managing fisheries systems (Lane and Stephenson 2000, Mahon et al 2008). Low priority is accorded to fisheries on the political agenda, owing to its low importance relative to other sectors such as tourism and industry in these countries. Stock assessment results and social and bio-economic information are rarely integrated into the policy-making process.

These issues are even more pronounced at the regional level. There is limited co-ordination, collaboration, and harmonization among the players and programmes in the Caribbean for management of transboundary living marine resources. As previously mentioned, transboundary living marine resources require coordinated and harmonized governance structures and policy cycles at local, national, sub-regional, regional, and where appropriate, global scales, with appropriate linkages between them. A number of the immediate causes identified might be best addressed at the local level, with the necessary governance structures in place at this level.

At the sub-regional levels, some measures are in place for harmonized management of shared resources (e.g. OSPESCA harmonized management plan for tunas in Central America; US Caribbean Fisheries Management Council management of Atlantic highly migratory species). Transboundary living marine resources require coordinated and harmonized governance structures that operate at the appropriate geographic scales. The large pelagic fisheries are currently served by a working international governance mechanism (ICCAT). However, Caribbean participation in ICCAT is weak, particularly by the small developing states (Mahon and McConney 2004). An inherent problem is the existing focus on management of single stocks rather than on maintaining the overall health of the Caribbean Sea ecosystems, on which fisheries resources are dependent.

Unsustainable development models

Governments often formulate development agendas to alleviate poverty, stimulate economic growth and provide employment, rather than ensuring sustainable development. Fisheries expansion programmes have been undertaken in this manner, without adequate knowledge about the stocks and considerations of longterm sustainability. This is also related to the political cycle in the countries, with planning processes linked to short-term horizons.

Population and cultural pressures

Caribbean pelagic fisheries resources, particularly the coastal pelagics, have been historically fished across the region, especially as the coastal areas are densely populated. Fish has historically been an important part of the diet of coastal communities, who depend heavily on reef fisheries as a source of food and livelihoods. Growing demand for fish and fishery products, resulting from population growth, increasing purchasing power, and improved awareness of the nutritional value of fish, has resulted in excessive pressure on the regions fisheries resources.

The relatively high poverty levels in some of the countries mean greater pressures on the fish stocks from people who have little alternatives for food and employment. Despite generally favourable social development rankings, poverty is a concern across the region (Brown et al 2007). In studies carried out in 2003 (Trotz 2003) found that 25% of the overall Caribbean population can be categorized as poor, with more women than men living in poverty. The coastal zone has been particularly important for the livelihoods of the poor, who exploit common pool resources such as fish. The coastal pelagic resources are an important part of the diet of local people and also provide considerable revenue, especially to poorer fishers lacking the means to exploit offshore resources.

Illiteracy, lack of other skills and unwillingness of some fishers to consider alternative employment and/or lack of other economic options continue to drive increased fishing pressure in some countries. High levels of unemployment in some areas force large numbers of persons to enter and remain in fisheries, which act as a safety net.

Inadequate knowledge and low public awareness

There is general poor understanding of environmental concepts and low public awareness about the importance of marine ecosystems in providing essential ecosystem services and the economic value of these services, particularly the non-tangible services. Fish catches are still seen as disconnected from the marine ecosystems from which they came and there is low awareness about the finite nature of marine living resources. This is changing in the region, however, with an upsurge in environmental education and awareness programmes. These are necessary to change perceptions and attitudes towards conservation and environmental responsibility. Where scientific knowledge is available, it is often poorly communicated to, and understood by policy-makers and the public.

High dependence on fish for income and export earnings

Large pelagic resources are highly sought after for food, export and recreational fishing in CLME countries. Government policy in many countries is to expand fisheries as a means of generating jobs, income and foreign exchange, most often without adequate knowledge about the resources. The large pelagic resources are of high value and expansion of the lucrative fisheries for these species has been largely export-driven. Massive investment in developing the fisheries for large pelagics drives high exploitation rates for these resources in order to maximize profits. Greed also drives some individuals to engage in unsustainable practices to maximize their profits.

Rising demand and increasing access to global markets promote heavy exploitation of the region's large pelagic resources. According to FAO statistics fish exports from the region amounted to around 200,000 tonnes, worth US$1.2 billion. Tunas and billfishes command premium prices on the international market and are among the dominant fish products exported by Caribbean countries. The high demand for shark fins in the Asian market also drives intense fishing pressure on vulnerable shark species. Although some countries such as Costa Rica has regulations that prohibit the transport, possession, and landing of shark fins, this illegal practice continues. Given the dependence of the region's fisheries sector on foreign markets where demand is strong, pressure on stocks will continue to rise, especially as there have been large capital investment in fisheries (particularly pelagic fisheries).

5.2.2. Habitat degradation and community modification

Sectors that contribute to degradation and community modification of the pelagic habitat: All key sectors including fisheries, tourism, agriculture and aquaculture, forestry, urbanization, industry, construction, shipping, and energy production. Almost all the key sectors contribute to habitat degradation and community modification in the Caribbean, including fisheries, tourism, agriculture and aquaculture, forestry, urbanization, industry, construction, shipping, and energy production.

Immediate causes

The principal immediate causes of habitat degradation and community modification of the pelagic ecosystem include pollution, overfishing, and global warming and climate change.

Pollution

Pollutants originate from land and sea-based sources and enter the sea from direct discharges, river runoff, diffuse input from land (leaching) and atmospheric deposition. Sewage is regarded as one of the most important and widespread causes of deterioration of the coastal environment in the Caribbean. Rapid population growth and tourism, urbanization, and the increasing number of ships and recreational vessels have resulted in the discharge of increasing amounts of poorly treated or untreated sewage into coastal waters. Sewage along with agricultural fertilizers contributes excessive amounts of nutrients to coastal waters, resulting in eutrophication, harmful algal blooms, and hypoxia in the water column. Sediments block sunlight, decreasing the photic layer and limiting algae growth and productivity of the water column. Shipping and activities related to the petroleum industry contribute significant pollution loads, including of oils, to the Caribbean Sea.

Overfishing and destructive fishing practices

High fishing pressure and selective fishing can alter the pelagic community structure. Selective fishing for top predators has led to a reduction in the abundance of these groups and a shift towards dominance by species at lower trophic levels ("fishing down the food web"). Unsustainable fishing has also reduced populations of marine mammals in the region.

Global warming and climate change

Degradation of the pelagic environment can occur through large-scale processes such as global warming and climate change. Empirical data on the impacts of climate change and global warming on the CLME's pelagic resources are unavailable. While mobile pelagic species are able to avoid localized degraded areas, less mobile species and early life history stages might not have this ability. Global and region-wide environmental stressors such as rising SST could have serious consequences for potential fisheries catches, as shown through modeling by Cheung et al (2009a). Global warming could alter oceanic processes and fronts, which can affect the abundance and distribution of pelagic resources. Rising SST can have major impacts on the CLME's living marine resources, many of which are already at the upper limit of their temperature tolerance ranges. Further, increasing carbon dioxide concentration in seawater (acidification) can dissolve or impair the formation of skeletons or shells of calcareous planktonic organisms.

Underlying Causes

Demography and urbanization

The coastal areas of the CLME are heavily populated, with concentration of urban areas, towns and villages as well as industrial and tourism infrastructure along the coast. This is of particular importance in the Insular Caribbean countries, whose entire land mass could be considered coastal because of their relatively small size. The overall average urbanization rate of Latin America and the Caribbean is projected to reach 84% in 2015. Much of this urbanization occurs in coastal areas, which will place increased pressures on the marine environment.

__Increasing demand for food production, employment and income__

Rising population will put more pressure on marine ecosystems as a result of increasing demand for living marine resources for food, construction material, as well as demand for employment and income (fisheries and tourism sectors). This will also extend to coastal and inland areas where increasing demand for food and housing for a growing population will see a rise in agriculture, mariculture, and other land use changes that could eventually affect marine ecosystems. Global demand for food is also rising, which drives an increase in the exploitation of living marine resources and in production of agricultural commodities for export. Unsustainable practices in these sectors result in degradation of marine habitats.

__Land use changes and poor agricultural practices__

Changes in land use in watersheds in the Caribbean have been the single greatest cause of ecosystem damage. Deforestation especially on hillsides and general poor agricultural and aquaculture practices all contribute sediment and pollution from agrochemicals, pesticides, and other toxic substances to coastal waters. In 2005, CLME countries used more than 1.7 million tonnes of fertilizers (UNEP-RCU/CEP 2010). The application of pesticides in seven countries (Colombia, Costa Rica, Dominican Republic, Honduras, Jamaica, Nicaragua and Panama) has been estimated at 76,000 tonnes between 1995 and 2001 (UNEP-RCU/CEP 2010). Eutrophication, harmful algal blooms and hypoxia are frequent occurrences that affect the CLME's pelagic system. In general, there is a low level of implementation of sustainable agricultural and industrial practices. Land use changes and water diversion also affect the natural flow of freshwater to coastal areas, disturbing the salinity regime.

__Poorly planned coastal development__

There is growing investment and development in coastal areas, much of which is tourism-related. Land reclamation, industrial and harbour installations, dredging or extraction of sediments, disposal of wastes and dredged material, recreational activities, military activities and aquaculture operations all tend to concentrate along the coast. Pressures associated with coastal development include habitat alteration, discharge of sewage and other pollutants, urban runoff, and increased sediment loads and solid wastes, which cause degradation of the pelagic ecosystem.

__Harmful tourism practices__

Tourism can have both direct and indirect impacts on pelagic habitats. Recreational activities such as sailing can have direct impacts, including from disposal of waste and oil spills. Indirect impacts relate to the development, construction, and operation of tourism infrastructure as a whole (resorts, marinas, ports, airports, etc.). Tourism-related sources of sewage pollution include hotels and resorts and, to a lesser extent, recreational vessels. The Caribbean is the world's major cruise destination, with 14.5 million cruise passengers visiting Caribbean ports in 2000 (Ocean Conservancy 2002, CTO 2002). During the period 1990-2000 the industry has grown annually by 6.5% (CTO 2002). The cruise ship industry contributes to a number of stressors (e.g. pollution from liquid and solid waste, vessel groundings), although efforts are being made to reduce the environmental impacts. The cruise ship industry contributes a number of stressors (e.g. pollution from liquid and solid waste), although efforts are being made to reduce the environmental impacts. Tourism is the fastest growing sector, which can see an increase in its impacts if appropriate measures are not taken.

Limited integrated watershed and coastal area management

Although initiatives are underway to develop IWCAM in the region, this is not effectively implemented in all the countries and is not yet mainstreamed into development planning. The sectoral approach to development is still the norm. Much of the region has no coastal zoning or coordinated inter-sectoral land-use planning to ensure sustainability, so development is haphazard and loosely controlled. Regional policies that promote the development of river basin, coastal and marine planning and management are generally absent.

Limited capacity for implementation and enforcement of habitat conservation measures

At present, there appears to be a mismatch between the technical and managerial capabilities of authorities in the region, and the scale of important transboundary problems related to overfishing, habitat destruction, pollution, unsustainable agriculture, and tourism. There is limited institutional and human capacity for implementation of measures to conserve Caribbean marine habitats and for enforcement of these measures at the local, national, and regional scales. This is demonstrated in the poor implementation and enforcement of the existing regional and international policy frameworks (e.g. SPAW Protocol, CBD) and of measures such as MPAs and no-take reserves. Only about 14% of the region's MPAs are partially or fully managed effectively. Lack of or poor enforcement continues to be a driver for unsustainable practices. Marine science and technology capacity, as well as the capacity of local communities to participate in conservation programes, is also inadequate in the region. Further, given the wide diversity in size and economic development among Caribbean countries, the capacity to participate in collective mechanisms will vary considerably (CARSEA 2007). Limited financial resources for implementation and enforcement of sustainable practices and low capital investment by both public and private sectors in these practices further compound the problem of habitat degradation in the region.

Inadequate data and information

Although there is an enormous body of data and information on the status of Caribbean habitats, the focus has been on reef and associated coastal habitats. The pelagic ecosystem (water column) is sometimes specifically mentioned in studies of pollution or pelagic living resources. There is limited knowledge about the impacts of human activities (both coastal and land-based) and natural stressors on the productivity and carrying capacity of pelagic ecosystems. Existing data and information at the regional level are still very scattered and fragmented, and there is need for greater harmonization and integration of data and information to effectively manage the shared living resources of the CLME.

Harmful subsidies and lack of incentives for sustainable practices

These include harmful agricultural subsidies, and lack of or limited incentives for sustainable practices in agriculture, tourism and other sectors. Substantial subsidies are provided for the purchase of agricultural fertilizers in some countries. There is also low awareness about sustainable practices in all sectors, although this is slowly changing.

Intensive maritime and petroleum activities

The Caribbean Sea is intensively used for shipping and petroleum exploration, extraction, refining, and transport. These activities can result in degradation of marine areas through pollution from hydrocarbons and other hazardous substances as well as through mechanical damage/loss of critical habitats. In addition, the high shipping traffic in the Caribbean Sea poses a significant potential danger from the introduction of marine invasive species. This underlying cause is discussed further in the Pollution CCA.

Inadequate waste management and disposal

Inadequate waste management and disposal result in pollution of coastal areas when waste is disposed at sea and through runoff from terrestrial areas. See Pollution CCA.

Root causes

Some of the socio-economic, legal, and political root causes of habitat degradation and community modification of the pelagic ecosystem are similar to those of unsustainable exploitation (e.g., growing human population, poverty, lack of alternatives for food and employment) and are not repeated here. Other root causes of habitat degradation include:

Poor governance

Efforts to protect marine ecosystems and resources have been fragmented and largely insignificant. For example, in the MAR countries, Belize has 2% of its marine territory in fully protected zones, followed by Mexico and Honduras with less than 1%, and none in Guatemala. Where protected areas exist, surveillance and enforcement are usually limited or non-existent. There is poor integration of environmental considerations into development planning in the region. Further, the management of the Caribbean Sea is characterized by uncoordinated efforts without any holistic integrated management plan. Management is organized primarily at the level of individual countries or political blocs, while what is required is to deal with marine environmental problems of the CLME at the scale of the entire ecosystem (CARSEA 2007). As previously mentioned, transboundary living marine resources require coordinated and harmonized governance structures and policy cycles at local, national, sub-regional, regional, and where appropriate, global scales, with appropriate linkages between them. A number of the immediate causes identified might be best addressed at the local level, with the necessary governance structures in place at this level.

The environment is given low priority on political agendas and over short-term economic development. Stakeholder involvement in the management of marine habitats and living resources is still relatively low, although there are many examples of this in the region.

See Fisheries and habitats CCA for other elements associated with poor governance.

Weak and ineffective legal and institutional frameworks

At the national level, legal and institutional frameworks are often weak and ineffective, due to a number of factors including fragmentation of responsibilities among various departments and limited coordination among them, limited cross-sectoral approaches in development planning, and inadequate human and financial resources. Where measures are in place to conserve reef habitats (e.g. MPAs), there is often poor management, surveillance, and enforcement. The relevant MEAs such as the SPAW Protocol, CBD, CCD, RAMSAR, etc. are still to be ratified by many of the Caribbean countries. The SPAW protocol has been ratified so far by only 13 Caribbean States. Moreover, in countries that have already ratified these MEAs, there is often poor implementation and enforcement at the national level. There are inadequate unified and harmonized frameworks for transboundary habitat issues at the regional level.

Trade and external dependency

The high dependence on international tourism and agricultural exports and in some cases limited opportunities for economic development in the countries (especially in the Insular Caribbean countries that have a very narrow natural resource base and opportunities for diversification) causes intense pressures on the region’s marine living resources and environment. Capital investment in Caribbean tourism is the highest in the world relative to its size, with a proportional demand for coastal infrastructure at the expense of coastal ecosystems.

Lack of economic valuation of ecosystems and their services

Apart from the value of tangible ecosystem services such as fish catch, the economic value of ecosystems and their services is largely unknown and go unrecognized and unaccounted for. Past attempts to estimate the value of ecosystem services provided by Caribbean habitats have focused on coral reefs in a few countries (Burke and Maidens 2004, Burke et al 2008, Cooper et al 2009, Wielgus et al 2010), which included mangroves in Belize (Cooper et al 2009). Similarly, the economic cost of habitat degradation in the Caribbean has been estimated only for coral reefs (Burke and Maidens 2004). Valuation of pelagic ecosystem services has not been undertaken for the CLME. Until the soco-economic value of the pelagic ecosystem and its services is recognized and accounted for in national development planning, this ecosystem will continue to be degraded.

Limited knowledge and public awareness

There is often limited knowledge, public awareness, and appreciation including about the importance of marine ecosystems and their services to food security and socio-economic development in the region, and of humans as an integral component of the CLME as well as of the vulnerability of these ecosystems. There is also low awareness about sustainable practices in all sectors that impact on the pelagic ecosystem. Furthermore, there is limited awareness about the shared nature of the Caribbean Sea and of the connectivity among its habitats and living resources. Wider Caribbean states have not grasped the possibilities under the various existing policy instruments for forging the kind of sub-regional and regional co-operation required for better management of the Caribbean Sea and its resources (CARSEA 2007). This situation is changing, however, with increasing educational and public awareness programmes in the region.

Population and cultural pressures

Increasing human population throughout the region is accompanied by rising demand for living marine resources as a source of food, income and employment, which will intensify the pressures on marine ecosystems. Higher populations also mean greater demand for food crops and livestock and associated requirements for agricultural land, for housing and infrastructure, and other services that could increase the pressures on the pelagic ecosystem (e.g. from land-based pollution). The relatively high poverty levels in some of the countries mean greater pressures on pelagic habitats from people who have little alternatives for food and employment. Many poor communities also engage in agriculture and livestock farming, which could contribute to degradation of the pelagic ecosystem (e.g. from excessive sediments and nutrients).

5.2.3. Pollution

Sectors that contribute to pollution of coastal and marine areas in the Caribbean: All the key sectors including fisheries, tourism, agriculture and aquaculture, urbanization, industry, shipping, transport/infrastructure, and petroleum exploration, extraction, refining and transport. The principal immediate causes of pollution of the pelagic ecosystem include a wide range of substances, some of which have greater impacts than others.

Immediate causes

The principal immediate causes of pollution of the pelagic ecosystem include:

Sewage

Domestic and industrial sewage (municipal effluents) constitutes the largest volume of waste discharged to marine ecosystems. Sewage is discharged mainly by cities as domestic and industrial wastes, aquaculture facilities and other types of developments and activities, and from ships (illegally and legally permissible under the MARPOL), including cruise ships and recreational vessels. Sewage contains a number of substances (e.g. nutrients, pathogens, heavy metals) that can reduce water quality and degrade the pelagic ecosystem. Nutrients contained in sewage cause eutrophication, which can promote HABS and subsequent hypoxia and fish kills.

Nutrients

High nutrient loads (nitrogen and phosphorus) in coastal areas arise mainly from sewage outflow and agriculture and aquaculture runoff, which increase during periods of heavy rainfall. Sewage is also discharged from ships and recreational boats. The total estimated nutrient load to the Caribbean Sea has been estimated at 722,000 tonnes per year of total nitrogen and 136,000 tonnes per year of total phosphorus (UNEP-RCU/CEP 2010). Excessive nutrient inputs cause eutrophication of coastal waters, which can result in HABs, hypoxia, and fish kills. High inputs of untreated or partially treated sewage into coastal areas, along with other contaminants, are responsible for a number of coastal hotspots in the region.

Sediments

Considerable quantities of suspended sediment are introduced by rivers and watercourses to the coastal areas of the CLME. Rivers from both within and outside the Caribbean region deposit enormous quantities of sediments in coastal waters annually. The Magdalena River in northern Colombia, which has the highest freshwater discharge of all Caribbean rivers, contributes an estimated 144 tonnes/yr. Significant quantities of freshwater and sediments also come from rivers outside of the CLME (Amazon and Orinoco Rivers). As seen in Figure 46, (Muller-Karger et al. 1989) an enormous plume of freshwater from the Orinoco extends into the Caribbean Sea, affecting mainly the Lesser Antilles. This outflow is known to introduce sediments and other substance into the CLME. Annual sediment input to the CLME region has been estimated at about 216 million tonnes (excluding inputs from the Orinoco due to insufficient data) (UNEP-RCU/CEP 2010). In addition to increasing water turbidity, sediments particles may carry pollutants such as heavy metals and pesticide residues as well as microbes, which are harmful to marine organisms and to humans. In recent years suspended sediment loads to the Caribbean Sea have increased substantially as a result of poor land use practices and land use changes, land degradation, and soil erosion. High suspended sediment levels also arise from dredging in harbours and from coastal erosion.

Hydrocarbons

Oil spills associated with industry, shipping and offshore operations constitute one of the greatest environmental threats to the WCR. In general, the major concern of contamination from petroleum hydrocarbons in the Caribbean region is from accidental events, such as large oil spills, although there is evidence of chronic hydrocarbon pollution in some areas. A number of coastal hotspots in the WCR show continuing high levels of hydrocarbons.

Oil and its refined products are a complex mixture of substances such as PAHs, aliphatic hydrocarbons, alkanes, waxes, olefins, benzenes, and trace metals, some of which could be highly toxic to marine organisms. Dispersants used in oil spills and derivate substances may be toxic at low concentrations to marine organisms. Although of great concern, long-term effects of hydrocarbons in the pelagic ecosystem are generally limited, and largely affect sea birds, turtles, marine mammals, and sensitive invertebrates, in addition to sensitive coastal habitats such as mangroves and seagrass beds. Large spills can have devastating short-term lethal and sub-lethal consequences for local flora and fauna.

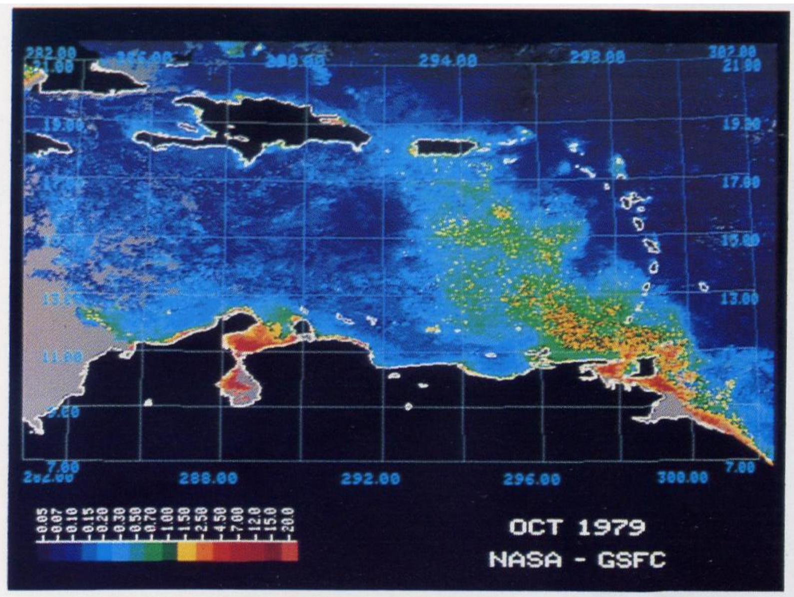

PLATE 5. October 1979. CZCS composite of 9 overviews of the Caribbean Sea in October 1979. The Orinoco plume occupied the eastern Caribbean and flowed northwestward past Puerto Rico. A small plume veering offshore near 10° N, 59° W was evidence of an anticyclonic eddy east of Trinidad.

Figure 46. Satellite image showing the Orinoco River plume in the Caribbean Sea

Agricultural chemicals

Large quantities of fertilizers and pesticides are extensively used in agriculture and reach the coastal and marine environments via rivers and atmospheric transport. Cultivation on steep slopes promotes soil erosion and the rapid movement of these chemicals to coastal areas. Together with sewage, agricultural fertilizers are the most important contributors to the increase of nutrient loads to coastal areas, leading to eutrophication (Gil-Agudelo and Wells, in press). Agrochemicals also include a wide range of pesticides (herbicides, insecticides, fungicides, and other compounds) commonly used to increase crop yields and to control weeds and insect pests. Agrochemicals are slow to degrade and persist in the environment, and they bioacumulate and biomagnify through the food web. (See below Heavy metals and POPs)

Heavy metals and POPs

Heavy metals and POPs originate from a number of sectors including the industrial, agricultural and transportation sectors. Industrial wastes are often discharged untreated and frequently contains heavy metals and POPs. A number of coastal pollution hotspots in the WCR show elevated levels of heavy metals (UNEP-RCU/CAR/Cimab 2010). In addition to direct impacts on the pelagic ecosystem, these substances bioaccumulate and biomagnify in the food chain, with potentially detrimental effects on top predators and eventually humans. Mercury is of particular concern in this regard. Heavy metals and substances like tributyl tin are found near cities, ports, and industrial developments across the region. Traces of some of these contaminants have been found in remote areas, with unknown impacts in these ecosystems (Gil-Agudelo and Wells, in press). Mercury is being carried through the region by ocean currents, with high concentrations of this metal being found even in 'pristine' reefs (Gil-Agudelo and Wells, in press). Some agricultural chemicals are also POPs.

Solid waste

Solid waste is composed of a range of material and originates from all sectors as well as from domestic and municipal sources. The composition of solid waste continues to change from mostly organic to inorganic, non-biodegradable material such as plastics. Most plastics are virtually indestructible and can accumulate over time, creating ecological and aesthetic problems. Rivers, watercourses and coastal wetlands have been converted into garbage dumps, from where solid wastes enter into coastal areas. During the rainy season, the movement of waste of all kinds, including solid waste, is considerably high. In some areas, a thick layer of solid waste is formed, for example in Kingston Bay (UNEP-RCU/CAR/Cimab 2010). Solid waste also originates from fishing activities, tourism, shipping and recreational vessels.

Underlying causes

Some of the underlying causes of pollution are similar to those of habitat degradation.

Demography and urbanization

The coastal areas of the CLME are heavily populated, with concentration of urban areas, towns and villages as well as industrial and tourism infrastructure along the coast. This is of particular importance in the Insular Caribbean countries, whose entire land mass could be considered coastal because of their relatively small size. The overall average urbanization rate of Latin America and the Caribbean is projected to reach 84% in 2015. Much of this urbanization occurs in coastal areas, which will place lead to increased pollution of the marine environment if adequate measures are not implemented to address pollution.

Inadequate waste management and disposal

Inadequate waste management and disposal result in pollution of coastal areas when waste is disposed at sea and through runoff from terrestrial areas. Countries have limited capacity for proper treatment and disposal of both domestic and industrial waste. The pattern of sanitation coverage in the region is extremely patchy in terms of its extent and treatment capabilities (Cimab 2010). In WCR countries, an important sector of the population lives in coastal areas where sewerage systems are deficient and even absent in some cases (Cimab 2010). Moreover, in countries that have sewer systems a shortage of sewage treatment plants or non-functioning plants is common. In the WCR, the average (unweighted) proportion of sewage that is treated is about 44% (UNEP-RCU/CAR 2010). There are about 58 submarine outfalls in the region (39 of which are in Venezuela)[18].

Proper management and disposal of industrial waste is also limited, including treatment of point sources of discharge and construction and maintenance of storage facilities for industrial waste. There have been some recycling programmes established in the region, but these need to be increased. The adoption of cleaner production technologies in industry has historically been inadequate, but this is slowly changing. There has been an increase in the industrial wastewater treatment capacities and disposal, in particular in the oil industry and the increase of the environmental awareness. Also, governments have increased demands on industry as regards environmental protection in the WCR in the recent years (UNEP-RCU/CAR 2010).

Improper land use and poor agricultural practices

Changes in land use in watersheds in the Caribbean have been the single greatest cause of coastal ecosystem damage. Deforestation especially on hillsides and general poor agricultural and aquaculture practices all contribute sediment and pollution from fertilizers, pesticides, and other toxic substances to coastal waters. Fertilizer, agro-chemical, and manure runoff from agricultural lands in upstream coastal areas of WCR countries are significant sources of nutrients and other agrochemicals to the marine environment from non-point sources. These contaminants are particularly prevalent because important crops like sugar cane, citrus fruits, bananas, grains and coffee require large amounts of fertilizers and pesticides. CLME countries used more than 1.7 million tonnes of fertilizers in 2005 (UNEP-RCU/CEP 2010). Annual fertilizer use by countries/territories is given in Annex 8. The application of pesticides in seven countries (Colombia, Costa Rica, Dominican Republic, Honduras, Jamaica, Nicaragua, and Panama) has been estimated at 76,000 tonnes between 1995 and 2001 (UNEP-RCU/CEP 2010). In general, there is a low level of implementation of sustainable agricultural practices.

[18] Based on national reports prepared for the Updated CEP Technical Report 33; and Salas, H. 2000. Emisarios submarinos. Alternativa viable para la disposición de aguas negras de ciudades costeras en América Latina y el Caribe. OPS/CEPIS/PUB/00.51.

Increasing demand for food production, employment, and income

Rising population will put more pressure on marine ecosystems as a result of increasing demand for living marine resources for food, construction material, as well as demand for employment and income (fisheries and tourism sectors). This will also extend to coastal and inland areas where increasing demand for food and housing for a growing population will see a rise in agriculture, mariculture, and other land use changes that could eventually affect marine ecosystems. Global demand for food is also rising, which drives an increase in the exploitation of living marine resources and in production of agricultural commodities for export. Unsustainable practices in these sectors result in degradation of marine habitats.

Poorly planned coastal development

There is growing investment and development in coastal areas, much of which is tourism-related. Land reclamation, industrial and harbour installations, dredging or extraction of sediments, disposal of wastes and dredged material, recreational activities, military activities and aquaculture operations all tend to concentrate along the coast. Pressures associated with coastal development include habitat alteration, discharge of sewage and other pollutants, urban runoff, and increased sediment loads and solid wastes, which cause degradation of the pelagic ecosystem.

Harmful tourism practices

Tourism can have both direct and indirect impacts on reef habitats, including from disposal of waste and oil spills. Tourism-related sources of sewage pollution include hotels and resorts and, to a lesser extent, recreational vessels. The Caribbean is the world's major cruise destination, with 14.5 million cruise passengers visiting Caribbean ports in 2000 (Ocean Conservancy 2002, CTO 2002). During the period 1990-2000 the industry has grown annually by 6.5% (CTO 2002). The cruise ship industry contributes to a number of stressors (e.g. pollution from liquid and solid waste, vessel groundings), although efforts are being made to reduce the environmental impacts. Tourism is the fastest growing sector, which can see an increase in its impacts if appropriate measures are not taken.

Intensive maritime and petroleum activities

The Caribbean Sea is intensively used for shipping and petroleum exploration, extraction, refining, and transport. These activities present a high risk of pollution in the region. The main causes of elevated hydrocarbon concentrations in the region are leaching of drilling oils and other residues from the oil industry, vandalism, shipping traffic discharges (mainly bilge oil and fuel oil sludge), and accidents (INVEMAR 2007, PNUMA 2007). High shipping traffic in the Caribbean Sea poses a significant potential danger from oil spills and other hazardous substances, as well as from ballast water. During the period 2003-2004, ship traffic in the Caribbean Sea was estimated as an average of 8,664 ships per month and 285 ships per day, much of this associated with the Panama Canal. In 2005, six million tonnes of ballast water were poured into the Caribbean Sea, of which 84% came from international shipping. About 7 million barrels of oil are discharged annually from ship tank washings.

Root causes

Poor governance

Efforts to protect marine ecosystems and resources have been fragmented and largely insignificant. There is poor integration of environmental considerations into development planning in the region. Further, the management of the Caribbean Sea is characterized by uncoordinated efforts without any holistic integrated management plan. Management is organized primarily at the level of individual countries or political blocs, while what is required is to deal with marine environmental problems of the CLME at the scale of the entire ecosystem (CARSEA 2007). As previously mentioned, transboundary living marine resources require coordinated and harmonized governance structures and policy cycles at local, national, sub-regional, regional, and where appropriate, global scales, with appropriate linkages between them. A number of the immediate causes identified might be best addressed at the local level, with the necessary governance structures in place at this level.

The environment is given low priority on political agendas and over short-term economic development. There is limited investment in pollution control and waste treatment facilities. Stakeholder involvement in the management of marine habitats and living resources is still relatively low, although there are many examples of successful stakeholder involvement in the region. Despite the existence of regional and international policy frameworks related to pollution, a harmonized governance mechanism at the regional level to address transboundary pollution is lacking. A number of the following causes are also related to governance.

Weak and ineffective legal and institutional frameworks and poor enforcement

At the national level, legal and institutional frameworks to address pollution are often weak and ineffective, despite the existence of a number of relevant laws and regulations related to pollution. The relevant MEAs such as the LBA and Oil Spill Protocols, MARPOL, and Ballast Water Convention are still to be ratified by many of the Caribbean countries.

Annex 9 shows that a number of countries are yet to ratify/accede to the Cartagena Convention and the LBA and Oil Spill Protocols. Moreover, in countries that have already ratified these MEAs, there is often poor implementation, compliance, and enforcement. Monitoring and enforcement of the implementation of these MEAs are the responsibility of national governments, which often lack the capacity and the political will to fulfill their obligations.

Inadequate environmental quality standards and legislation

Most of the WCR countries do not possess national environmental quality norms for coastal areas or in other cases they exist but are incomplete (UNEP-RCU/CEP/Cimab 2010). Where these exist, there is often poor compliance, monitoring and enforcement. National programmes do not usually address regional concerns and focus on addressing domestic impacts, rather than those occurring outside of territorial limits or in international waters.

Inadequate data and information

Because of limited financial and human resources and other factors, pollution monitoring, control, and assessment activities are weak and inadequate. While numerous studies have been conducted in localized areas, most are sporadic and limited in scope. There are no systematic regional monitoring and data sharing programmes (apart from the monitoring of dust) that specifically focus on transboundary pollution and its impacts. Moreover, methodologies are often not standardized and harmonized, even the national level, which makes it difficult to compare status and trends. In general the quality of regional environmental data is low, as few countries have the necessary systems in place to collect quality-assured environmental data on a regular basis. This is being addressed however, as demonstrated by recent reports on pollution from UNEP-RCU/Car and Cimab. These studies have pointed out a number of data and information gaps both with respect to particular substances and coverage among the countries. Collection of data and information on the impacts of pollution on marine habitats and their living resources, as well as socio-economic impacts and costs need to be improved.

Limited financial and human resources

Many of the CLME countries lack the necessary financial resources for construction and/or maintenance of sewage treatment plants and industrial and other waste treatment infrastructure. Inadequate financial and human resources also contribute to inadequate monitoring, surveillance, and pollution assessment activities. Attempts to implement the 'polluter pays' principle can be fraught with considerable difficulties.

Low awareness of the value of the environment

The sea is generally seen as a receptacle for waste, with unlimited capacity to absorb the wide range of substances and materials that are disposed in coastal and marine areas. It is a common practice in the region's coastal towns to discharge domestic wastewater (treated or otherwise) into the nearest or most convenient body of water, in many cases because of lack of knowledge and indifference to the damage this causes to the environment and to public health. Awareness of the socio-economic and ecological value of marine and habitats and marine living resources is limited. In general, there low public awareness about the relationship between development and environmental protection, and between overall ecosystem health and the production of ecosystem services. This contributes to the low priority given to the environment on the political agenda.

6. INTERLINKAGES WITH OTHER TRANSBOUNDARY ISSUES

The CLME is impacted by a range of human and natural pressures, which degrade its overall health, individually and synergistically, and in many cases still unknown ways. Decline in ecosystem health has serious implications for the provision of ecosystem services by the CLME. The close interlnkages among the three priority transboundary issues demonstrate the need for a holistic, integrated approach in managing the CLME's living marine resources.

Overexploitation is closely linked with habitat degradation, particularly of coral reefs, mangroves, and seagrass beds, which provide shelter and feeding and nursery grounds for fish and invertebrates of commercial importance. Degradation of these habitats (including from pollution) could lead to a reduction of the stocks of those species that depend on these habitats. Further, destructive fishing gear and practices could destroy habitats through physical damage. Degradation of the pelagic ecosystem could affect both pelagic resources as well as reef resources that have pelagic eggs and larvae. Overfishing of herbivores on reefs has already been shown to contribute to overgrowth of reefs by algae. Fish stocks are also affected by pollution and climate change.

Habitat degradation and community modification are closely linked with unsustainable exploitation, in contributing to declines of fish populations through loss of shelter, nursery, and feeding grounds. This problem is also linked with pollution, which is one of the major causes of degradation of coastal habitats in the region. In turn, degradation of mangroves and seagrass beds results in reduction in the ecosystem service of water purification and nutrient cycling, thus increasing the impact of pollution in adjacent coral reefs and exacerbating their degradation. Habitat degradation and community modification is also linked with global climate change. In addition to the direct impacts of climate change (e.g. coral bleaching), degraded habitats are less resilient to external perturbations such as climate change. Widespread loss of habitats such as seagrass beds and mangroves could also exacerbate climate change by reduction in their carbon sequestration function.

Pollution is linked with habitat degradation and overexploitation by causing deterioration of environmental quality and ecosystem degradation, and as a result, reduction in overall productivity. It can also be linked to decline of marine resources by causing direct mortality. Habitat degradation can also lead to increased pollution, for example, loss of mangroves could result in increased levels of pollution reaching adjacent coral reefs.

7. KNOWLEDGE GAPS

The following presents a list of knowledge gaps for the three priority issues. This list is not meant to be exhaustive, and as the SAP is developed and specific priority actions identified, specific knowledge can be identified.

7.1. Unsustainable exploitation

- Knowledge gaps include basic data and information about fish stocks that are required for reliable stock assessment and management (both from the resource side such as stock sizes and species taxonomy and identification, and from the fisheries side such as fishing effort, total catch and economic information). Considerable knowledge gaps still exist, particularly with respect to transboundary resources. Management of these resources should be based on the status of the stock evaluated at the scale of the entire stock.
- There is a high degree of uncertainty in the spatial oceanic dynamics of migratory species, and there is a need for standardized indices of abundance, sustainable yield, and fishing effort for these resources. Significant gaps still exist on the biology and population dynamics of individual species.
- The move towards more integrated, holistic (e.g. ecosystem) approaches to living marine resources management has revealed major gaps in the knowledge required to implement these approaches. For instance, there is limited knowledge about ecological interactions within fish communities, on the impacts of fishing and other pressures on ecosystem structure and function. These gaps are significant within national boundaries, and even more so at the sub-regional and regional scales. Holistic, multisectoral approaches require knowledge, for example, about the synergies among the various sectors and their combined pressures on living marine resources, and the linkages between humans and marine living resources.
- Knowledge on the response of the region's marine ecosystems and fish populations to global climate change (e.g. changes in productivity, migratory patterns) would help in developing and implementing appropriate adaptive and mitigation strategies.
- The establishment of MPAs, marine reserves, no-take fishery zones, etc. is widely advocated. However, in order to derive maximum benefits from these areas, their establishment and management must be based on relevant scientific knowledge, much of which is lacking in the region. This includes knowledge on the connectivity among habitats, dispersal of larvae, patterns of movement during the juvenile and adult phases, knowledge of the ecosystem impacts of fishing, and socio-economic knowledge required for effective management of these areas.
- Sustainable levels of total catch and corresponding fishing effort levels (including artisanal and industrial) for exploited stocks and stock for which fisheries are developing.

- A number of gaps exist regarding spawning aggregations (including sustainable level of catch and required effort; the region from which the spawning aggregation population is drawn, adult migration routes; trajectory and dispersal of eggs from spawning areas; and barriers to and corridors that enhance connectivity).

7.2. Habitat degradation

- Ecosystem structure and function, and inventory of marine species;
- Spatial extent and distribution of habitats (habitat mapping);
- Economic value of coastal and marine ecosystems and services. Focus should be on the marginal economic value, which would allow economic changes associated with changes in ecosystems to be determined;
- Social and economic cost of degradation (including the cost of addressing habitat degradation);
- The degree of connectivity and interdependence among the habitats within the CLME as a whole; and connectivity with other areas of biological importance and with protected areas;
- Thresholds at which damage to habitats are irreversible;
- Ecosystem carrying capacity with respect to tourism.

7.3. Pollution

- Quantitative data on the transboundary dispersal of pollutants in the Caribbean region as a whole.
- There is an urgent need for regular and long-term monitoring of pollution in the Caribbean Sea, both at the source and in the coastal and marine environment, including areas that may be affected far from the source.
- The impacts of pollution on sensitive habitats, on living marine resources, and on human health. For instance, data on bioaccumulation of pollutants in marine organisms and impacts on human health (including bioaccumulation in humans) when consumed are limited.
- The absence of clear targets and indicators, which makes it difficult to assess the impacts of marine pollution, as well as progress in addressing this problem, in concrete terms.
- Indicators to measure economic losses caused by pollution on fisheries, the tourism industry, and other economic activities. Correspondingly, there is a lack of data for economic valuation of environmental damage from pollution.

8. AREAS FOR FUTURE INTERVENTION

There is a wide array of global and regional legal instruments, agreements, arrangements and action plans that are directly relevant to the management of the living marine resources of the Caribbean Sea. These cover diverse issues such as the dumping of garbage, land-based pollution and oil spills, shipment of toxic wastes, the conservation of biodiversity, and sustainable fisheries, which are all very pertinent to the three transboundary issues identified in the CLME. Application of these instruments, nationally and sub-regionally, and implementation of their provisions, is rudimentary and they are often not reflected in national legislation (CARSEA 2007). Where these are incorporated at the national level, often they are not effectively implemented and enforced due to a number of reasons including limited capacities and financial resources of the countries. There should be greater focus on improved implementation of existing, rather than development of more policies, strategies, and action plans. While actions at the national level will also benefit transboundary living marine resources and issues, to be more effective in addressing transboundary issues requires that these be undertaken within a broader framework - sub-regional and/or regional, depending on the geographical distribution of the resources or the scale of the issue.

Where possible, consideration of transboundary issues should be incorporated within a collaborative and harmonized framework. The need for improved regional collaboration and cooperation, and appropriate institutional, legislative, and policy frameworks at the appropriate scale for shared resources has been extensively discussed (e.g. Mahon and McConney 2004, CARSEA 2007). The Governance paper prepared under the CLME project presents an analysis of the existing frameworks for transboundary living marine resources.

Developing these multi-scale frameworks and their effective functioning would need to be underpinned by credible data and information at the appropriate scale. This underscores the need for an improved mechanism for collecting data in a harmonized manner and for sharing data and information throughout the region. Addressing transboundary issues will also need further strengthening of the appropriate human capacity, much of which already exists in the Caribbean. A mechanism is needed to share existing human capacity, as well s experiences and best practices at the regional level and to pool financial resources, to help make existing and planned initiatives and their outcomes more sustainable.

EBM/EAF approaches are increasingly being accepted as the most appropriate frameworks to manage living marine resources, including shared resources. The nature of the CLME and its shared resources as well as its shared and common problems makes it an ideal candidate for EBM/EAF approaches, which puts emphasis on, among other aspects, maintaining the overall health of the ecosystem in order to maintain the production of ecosystem services as well as on the role of humans as a vital part of the ecosystem. The Regional Symposium (Towards Marine Ecosystem-Based Management in the Wider Caribbean) that was held in Barbados in 2008 (Fanning et al, in press) brought together a number of experts to discuss EBM/EAF issues in the Caribbean region. The various contributions at the symposium provide valuable information and a vast range of recommendations on implementing EBM/EAF approaches in the management of the CLME and its living resources. These recommendations, which are all endorsed in this TDA, would provide much needed guidance in developing interventions during preparation of the SAP. Similarly, the results of ecological modeling carried out by the LAPE project, despite some uncertainties, provide an important basis for moving forward with EBM/EAF for the pelagic ecosystem (Mohammed et al 2008).

Examples of specific interventions are given below. This list is not meant to be exhaustive, and specific options will be evaluated during development of the SAP. The focus of this section is on technical interventions rather than on those related to institutional, legislative, and policy aspects. It is recognized, however, that these aspects are an important component of the management of the region's transboundary living marine resources.

Unsustainable exploitation

- ✓ Improved implementation of existing policy frameworks to address unsustainable exploitation of living marine resources;
- ✓ Reduction in fishing effort for overexploited stocks. This has complex socio-economic implications, and must be accompanied by creation of alternative employment opportunities as well as the provision of alternative sources of protein for the communities that depend on these resources for employment and food;
- ✓ Elimination of destructive fishing gear and unsustainable fishing practices, including IUU fishing, Flags of Convenience and perverse incentives;
- ✓ Clear delimitation and mapping of EEZs, which is an issue of concern in the Caribbean SIDS;
- ✓ Establish economic measures and incentives to achieve compliance with regulations and promote sustainable practices;
- ✓ Co-operation in management among the key sectors (artisanal and industrial harvesting, processing and marketing sectors), as well as the relevant institutions in the countries, indigenous communities and regional and non-governmental organizations;
- ✓ Promotion of ecolabelling of fisheries products that come from sustainably managed stocks. This should be accompanied by enhanced environmental education in the countries;
- ✓ Use of the best available scientific information, with a conservative precautionary and adaptive approach to management. Filling knowledge gaps needs a significant investment in targeted research, mainly in the context of adaptive management. This will require the development of strong collaborations among the scientific, management, and stakeholder communities, including at the sub-regional and regional levels;
- ✓ Harmonization at the regional level of the collection of data and information required for stock assessment and management (e.g. fishing effort, total landings by species, origin of catches), and identification of the stock structure of transboundary species;

- ✓ Implementation of ecosystem based approaches, at the appropriate geographical scales. The ecosystem approach to fisheries management is increasingly being seen as the most effective strategy for management and conservation of living marine resources;
- ✓ Establishment/strengthening and effective management of a sub-regional/regional network of marine parks and protected areas, including no-take reserves that provide tangible economic, social and environmental benefits to coastal communities, based on sound science (see below on options for habitat degradation);
- ✓ Protection of fish spawning aggregations and other vulnerable populations and species;
- ✓ Maintenance of connectivity in reef and pelagic ecosystems. The collaborative design and implementation of networks of marine reserves that include multi-species spawning aggregation sites, critical nursery habitat, and their connectivity, are likely to provide an important contribution to reversing the decline in fisheries in the Caribbean. Resource managers should identify and protect multi-species spawning aggregations and critical nursery grounds for fishes;
- ✓ Develop regional accords and actions that recognize and embrace human, political, oceanographic, and biological connectivity towards the management of Caribbean marine resources, which depends on regional collaboration and policy harmonization. The needs for priority observations and research include: Identify and characterize important nursery habitats; characterize multi-species spawning aggregations; track initial trajectory and dispersal of eggs from spawning areas; map adult migration routes and genetic distributions of various species and taxa; identify barriers to and corridors that enhance connectivity; collect detailed bathymetric data for spawning and nursery areas, and oceanographic data with time series at spawning areas; and increase the use of remote sensing data.

Habitat degradation and community modification

Several of the policy frameworks and options to address unsustainable exploitation (as well as pollution) are also relevant to habitat degradation and community modification. Options for addressing habitat degradation and community modification include:

- ✓ Improved implementation of existing policy frameworks to address habitat degradation;
- ✓ Protection of healthy habitats;
- ✓ Incorporation of action plans for the Caribbean focused on restoration of coral reefs, mangroves, and seagrass beds; control of herbivore extraction and enhancement of herbivore populations on Caribbean reefs;
- ✓ Address invasive species, in particular development of an action plan for the lion fish in the Caribbean;
- ✓ Incorporation of coral bleaching into marine reserve design;

- ✓ Creation of livelihood enhancement and diversification strategies to reduce fishing pressure on reefs;
- ✓ Reduction of threats from both marine and land-based sources, including domestic and industrial wastewater and agricultural run-off;
- ✓ Adoption of integrated watershed and coastal area management;
- ✓ Promotion of sustainable fisheries, agriculture, and tourism practices;
- ✓ Incorporation of the economic value of ecosystem services in development planning;
- ✓ Develop comprehensive regional strategies and policy alternatives that address current and emerging threats to coastal habitats and their living resources as well as to human communities;

A toolbox for interventions to address coral reef degradation has been compiled by Mumby and Steneck (2008), and reproduced in Table 18. The sources of the information in this table are given in the paper by these authors.

The current focus of coral reef management often centers on the establishment of marine reserves that in practice are often too small, scattered, or have low stakeholder compliance; new approaches are needed to sustain ecosystem function in exploited areas (Mumby and Steneck 2008). Reef fisheries management has focused on the sustainability of harvested species and usually ignored the impacts of harvesting on the ecological processes that drive the ecosystem (including providing habitat for various fisheries species). According to Mumby and Steneck (2008) it is not enough to rely on marine reserves to manage coral communities; appropriate fisheries policies are also needed that explicitly consider the impacts of harvesting on herbivory. Fisheries policies need to be integrated with other efforts to scale up coastal protection such as establishing truly integrated governance structures for coastal management that extend from the watershed throughout the reef system. Multi-scale solutions to effectively conserve marine ecosystems Caribbean-wide will require reaching across borders. Reproductive stocks outside no-take reserves should be enhanced and protected (Steneck et al 2009). Special protection of ecologically important species (e.g., some herbivores in the Caribbean) and size-regulated fisheries that capitalize on the benefits of no-take reserves and maintain critical ecological functions are examples of measures that coalesce marine reserve effects and improve the resilience of coral reef ecosystems.

Maintaining ecosystem connectivity is an important consideration in management of fisheries and habitats. As previously discussed, there are close interlinkages between mangroves, seagrass beds and coral reefs (including high demographic connectivity). Current rates of loss of mangroves and seagrass beds are likely to have severe consequences for the ecosystem function, fisheries productivity and resilience of reefs. Conservation efforts should therefore protect connected corridors of mangroves, seagrass beds and coral reefs and facilitate the natural migration of species among habitats (Mumby 2006a). Knowledge of connectivity will help in deciding whether to create a single large or several small MPAs in a particular location.

Table 18. Available toolbox for addressing problems on coral reefs

Documented problem and cause	Expected consequences	Management tools
Global		
Ocean acidification (rising carbon dioxide concentration)	↑ Disease and fragility in calcifying organisms; ↓ growth rate of calcifying organisms; ↓ reduced coral-based services[a]	No direct, short-term solution (NS); facilitate coral recovery by managing herbivores and water quality (RECOVERY[b])[c]
Coral bleaching (global warming)	↑ Disease in calcifying organisms; ↓ reduced coral-based services[a]	NS; RECOVERY; place MRs in areas of low thermal stress[d]
Sea-level rise (global warming)	↑ Flooding; ↑ coastal erosion; ↓ freshwater; ↓ land area	NS; RECOVERY; sea defences[e]
Low fisheries yield (overfishing)	↑ Economic hardship for fishers; ↓ biodiversity and ecosystem function	↓ Fishing effort (EFFORT); MRs; ↓ loss of mangrove nursery habitats; ↑ alternative livelihoods; ↓ international export of reef fishes
Local		
Crown-of-thorns starfish outbreaks (agricultural runoff and/or fishing of predators)	↓ Reduced coral-based services[a]	Watershed management (WATER)[b]; EFFORT
Algal blooms (fishing of herbivores, eutrophication)	↓ Reduced coral-based services[a]; ↓ public health	WATER; EFFORT; RECOVERY
Rising number and prevalence of diseases (high physiological stress; nutrient runoff[f])	↓ Reduced coral-based services[a]	NS; WATER; RECOVERY
Tropical cyclone damage[g] (warm oceans)	Areas of extensive coral mortality; reduced resilience of reefs locally	NS; RECOVERY
Invasive species (release of ballast; aquarium discharge)	Disease (e.g. loss of Caribbean *Diadema*); disrupt trophic pathways (e.g. novel predator *Pterois volitans* in Bahamas)	Enforce and implement controls to ballast water treatment

Arrows directions denote increasing or decreasing trends. Management tools are: MR = marine reserves.

A Coral-based services include diversity and density of invertebrates and vertebrates (particularly small reef fishes), coastal defence from storms, reduced beach erosion, sediment production, fisheries production, aquarium-trade industry, diving and fishing tourism.

B RECOVERY includes reduce fishing effort (EFFORT) and watershed management of agrichemicals, sewage and sediment runoff (WATER).

C Much uncertainty about consequences and efficacy of tools in this context.

D Appropriate design of MRs unknown.

E Defences are expensive, and so are restricted to affluent areas.

F Causative agents and treatments are often unknown.

G Only a problem when combined with overfishing and poor watershed management.

Pollution

Options to address marine and coastal pollution include a number of those recommended for habitats (and *vice versa*):

- ✓ Wider ratification and better implementation of the Cartagena Convention, particularly the Protocols related to oil spills and land-based pollution, and MARPOL Convention, as well as the GPA and other relevant policy frameworks. Implementation could be improved by ensuring that existing policies, strategies, and action plans are realistic and accompanied by a strategic planning and financing strategy;
- ✓ Adoption and enforcement of environmental standards and better implementation and enforcement of the 'polluter pays' principle at national and regional levels. This would require the development of appropriate legal and institutional frameworks, as well as knowledge on the economic and social costs of habitat degradation and loss from pollution;
- ✓ Improved monitoring, including of transboundary movements of pollutants, using standard indicators and methodologies; and development of collaborative efforts to address transboundary pollution at the source;
- ✓ Adoption of a cross-sectoral approach in dealing with pollution, and a move towards an integrated, ecosystem approach where feasible. Since most of the pollution in the marine environment originates from land-based sources, integrated watershed and coastal area management (IWCAM) should be more widely implemented. The GEF IWCAM project as well as a number of other initiatives in the region to address pollution; the best practices and lessons learned should be adopted by other countries.

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REFERENCES

Agard, J., Kishore, R. and Bayne, B. 1992. *Perna viridis* (Linneaus 1758): first record of the Indo-Pacific green mussel (Mollusca: Bivalvia) in the Caribbean. Caribbean Marine Studies 3:59-60.

Agnew et al 2009

Agudelo, L. 2007. Mesoamerican Reef Alliance ICRAN-MAR Project Terminal Report. International Coral Reef Action Network.

Albins, M.A. and Hixon, M.A. 2008. Invasive Indo-Pacific lionfish *Pterois volitans* reduce recruitment of Atlantic coral-reef fishes. Marine Ecology Progress Series, 367:233-238

Alvarez-Filip, L., Dulvy, N.K., Gill, J.A., Côté, I.M. and Watkinson, A.R. 2009. Flattening of Caribbean coral reefs: region-wide declines in architectural complexity. Proc. Biol. Sci. 276(1669): 3019-25

Alverson, D.L., Freeberg, M.H., Pope, J.G. and Murawski, S.A. 1994. A global assessment of fisheries bycatch and discards. FAO Fisheries Technical Paper. No. 339. FAO, Rome.

Andrade, C. and Barton, E. 2000. Eddy development and motion in the Caribbean. J Geophys Res 105: 191–201.

Appeldoorn, R. S., E. Castro Gonzalez, R. Glazer and M. Prada. In press. Applying an Ecosystem-based Management to Queen Conch (*Strombus gigas*) Fisheries in the Caribbean. In: Towards Marine Ecosystem-Based Management in the Wider Caribbean. L. Fanning, R. Mahon and P. McConney (eds). Report of Caribbean Regional Symposium, University of the West Indies, Cave Hill Campus, Barbados, December 10-12, 2008.

Arocha, F., Marcano, L.A., Marcano, J.S., Gutierrez, X. and Sayegh, J. 2001. Captura incidental observada de peces de pico en la pesqueria industrial de palangre Venezolana en el mar caribe y en el Atlantico centro-occidental: 1991-1999. Col. Vol. Sci. Pap. ICCAT, 53: 131-140. (2001)

Arocha, F., Arocha, O. and Marcano, L.A. 2002. Observed shark bycatch from the Venezuelan tuna and swordfish fishery from 1994 through 2000. Col. Vol. Sci. Pap. ICCAT 54 (4): 1123- 1131.

Aronson, R.B. and Precht, W.F. 2000. Herbivory and algal dynamics on the coral reef at Discovery Bay, Jamaica. Limnology and Oceanography 45:251–255.

Arrivillaga, A. and Windevoxhel, N. 2008. Mesoamerican Reef Ecoregional Assessment: Marine Conservation Plan. The Nature Conservancy, Guatemala. 30 p. + Annexes.

Baker S.M., Baker P., Benson A., Nunez J., Phlips E. and J. Williams. 2002. Biopollution by the green mussel, *Perna viridis*, in the southeastern United States. 2002 Progress Report. EPA Grant Number: R828898.

Barreto C. G. and Borda C. A. 2008. Propuesta Técnica para la definición de Cuotas Globales de Pesca para Colombia, Vigencia 2009. Muñoz S. E., Puentes V., Sanabria, A.I. (Eds.). Documento Técnico concertado en el Comité Técnico Interinstitucional.

Ministerio de Agricultura y Desarrollo Rural, Ica, Ministerio de Ambiente y Vivienda y Desarrollo Territorial. 263p.

Behrenfeld, MJ, O'Malley R, Siegel D, McClain C, Sarmiento J, Feldman G, Milligan A, Falkowski P, Letelier R, Boss E. 2006. Climate-driven trends in contemporary ocean productivity. Nature 444:752-755.

Belausteguigoitia, J.C. 2004. Causal Chain Analysis and Root Causes: The GIWA Approach. Ambio Vol. 33 No. 1–2, 7-12.

Belkin, I.M., Cornillon, P.C., and Sherman, K. (2009). Fronts in Large Marine Ecosystems. Progress in Oceanography, 81(1-4): 223-236.

Beltrán, J., Martín, A., Aguilar, C., Ruiz, F., Regadera, R., Mancebo, H. and Helen, A. (2002). Control y Evolución de la Calidad Ambiental de la Bahía de La Habana y el Litoral Adyacente. Informe Nal. Vigilancia Ambiental para la Bahía de La Habana. Centro de Ingeniería y Manejo Ambiental de Bahías y Costas (Cimab), Cuba.

Benson, A. J., D. C. Marelli, M. E. Frischer, J. M. Danforth, and J. D. Williams. 2001. Establishment of the green mussel, *Perna viridis* (Linneaus 1758) (Mollusca: Mytilidae) on the west coast of Florida. J. Shellfish Res. 20(1):21-29.

BEST (2002). Bahamas Environmental Handbook. Bahamas Environment Science and Technology Commission. The Government of the Bahamas. Nassau, New Providence.

Bjorndal, K.A. and J.B.C. Jackson 2003. Roles of sea turtles in marine ecosystems: Reconstructing the past. In: P.L. Lutz, J.A. Musick, and J. Wyneken (Eds.), The biology of sea turtles, volume II. Pp.259-273. CRC Marine Biology Series, Boca Raton, Florida: CRC Press.

Botsford, L.W., J. W. White, M.A. Coffroth, C. B. Paris, S. Planes, T. L. Shearer, S. R. Thorrold and G. P. Jones. 2009. Connectivity and resilience of coral reef metapopulations in marine protected areas: matching empirical efforts to predictive needs. Coral Reefs. Published online February 2009 at Springerlink.com.

Bradley, P.E. 2009. Conservation of Caribbean seabirds. In P. Bradley and R. Norton (Eds.), An inventory of breeding seabirds of the Caribbean. Gainesville: University Press of Florida.

Brander, K. 2007. Global fish production and climate change. Proc Natl. Acad. Sci. 104, 19709–19714.

Bräutigam, A. and Eckert, K.L. (2006). Turning the Tide: Exploitation, Trade and Management of Marine Turtles in the Lesser Antilles, Central America, Colombia and Venezuela. TRAFFIC International, Cambridge, UK.

Brown, N., Geoghegan, T. and Renard, Y. (2007). A Situation Analysis for the Wider Caribbean. IUCN, Gland, Switzerland, 52pp.

Bryant, D., L. Burke, J. McManus, and M. Spalding. 1998. Reefs at Risk: A Map-based Indicator of Threats to the World's Coral Reefs. World Resources Institute. pp. 11-15.

Burke L. and Maidens, J. (2004). Reefs at risk in the Caribbean. Washington: World Resources Institute. 80 p.

Burke, L. and Z. Sugg. 2006. Hydrologic Modeling of Watersheds Discharging Adjacent to the Mesoamerican Reef. Analysis Summary. World Resources Institute.

Burke, L., Greenhalgh, S., Prager, D. and Cooper, E. 2008. Coastal Capital – Economic Valuation of Coral Reefs in Tobago and St. Lucia. World Resources Institute.

Burke, L. K. Reytar, M. Spalding and A. Perry. 2011. Reefs at Risk Revisited. World Resources Institute, Washington, DC.

Burkepile, D.E., Hay, M.E., 2010. Impact of herbivore identity on algal succession and coral growth on a Caribbean reef. PLoS ONE 5, e8963.

Cadogan, R. (2006). The viability of provisional arrangements for fisheries management pending boundary delimitation among member states of the Organisation of Eastern Caribbean States. PhD Thesis, UWI.

Carr, A., A. Meylan, J. Mortimer, K. Bjorndal and T. Carr. (1982). Surveys of sea turtle populations and habitats in the Western Atlantic. NOAA Technical Memorandum NMFS-SEFC-91. US Department of Commerce.

CARSEA 2007. Caribbean Sea Ecosystem Assessment (CARSEA). A sub-global component of the Millennium Ecosystem Assessment (MA), J. Agard, A. Cropper, K. Garcia, eds., Caribbean Marine Studies, Special Edition, 2007.

Castro, E., Heins Bent, Carlos Ballesteros, and Martha Prada. 2007. Large pelagics in the southern section of the Seaflower Marine protected area, San Andres Archipelago, Colombia: a fishery in expansion. Gulf and Caribbean Research 19(2): 1-10.

CATHLAC/Cimab. 2008. Estimación de la cargas de sedimentos en las Antillas utilizando el Modelo N-SPECT. Reporte. Cimab. La Habana, 8p

CFRAMP (2001). Report of the 2000 Caribbean Pelagic and Reef Fisheries Assessment and Management Workshop. CARICOM Fishery Report No. 9, 139 p.

Chakalall, B., Mahon, R. and McConney, P. (1998). Current issues in fisheries governance in the Caribbean Community (CARICOM). Marine Policy 22:29-44.

Chakalall, B. and Cochrane, K. (2004). Issues in the management of large pelagic fisheries in CARICOM countries, p 1-4 in: Mahon, R. and McConney, P. (eds), Management of Large Pelagic Fisheries in CARICOM Countries. FAO Fish. Tech. Pap. 464.

Charvériat, C. 2000. Natural disasters in Latin America and the Caribbean: an overview of risk. Inter-American Development Bank Research Department Working papers series, # 434)

Cheung, W.W.L., V.W.Y. Lam, J. L. Sarmiento, K. Kearney, R. Watson, D. Zeller and D. Pauly. 2009a. Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. Global Change Biology, 1-12.

Cheung, W.W.L., V.W.Y. Lam, J. L. Sarmiento, K. Kearney, R. Watson and D. Pauly. 2009b. Projecting global marine biodiversity impacts under climate change scenarios. Fish and Fisheries, 10, 235–251.

Chevalier, 2003

Christy, F. T. 1997. The development and management of marine fisheries in Latin America and the Caribbean. Policy Research Paper, Inter-American Development Bank.

Chuenpagdee R, Morgan LE, Maxwell S, Norse EA, Pauly D (2003) Shifting gears: Assessing collateral impacts of fishing methods in the U.S. waters. Frontiers in Ecology and the Environment 1(10): 517–524

Cimab, 2010. Baseline analysis on domestic wastewater management in the Wider Caribbean Region. Final Report, 41 pp.

Claro, R., and K. C. Lindeman. 2003. Spawning aggregation sites of snapper and grouper species (Lutjanidae and Serranidae) on the insular shelf of Cuba. Gulf and Caribbean Research 14 (2):91-106.

Clay, R., D. Wege, A. Sutton and V. Anadón-Irizarry (2005). Aquatic bird conservation in the Caribbean—next steps in delivering the Caribbean Waterbird conservation plan. J. Carib. Ornithol. 18:101-102, 2005

Conolly jr, Ewing M (1967) Sedimentation in the Puerto Rico Trench. J Sediment Res 37: 44–59.

Cooper, E., Burke, L. and Bood, N. 2009. Coastal capital: Belize. The economic contribution of Belize's coral reefs and mangroves. World Resources Institute, Working Paper.

Corredor, J., J. Morell, J. López, R. Armstrong, and A. Dieppa et al. 2003. Remote continental forcing of phytoplankton biogeochemistry: Observations across the Caribbean–Atlantic front. *Geophys. Res. Lett.* **30**(20): 2057. doi:10.1029/2003GL018193.

CRED (2005). Emergency Disasters Database. The International Disaster Database. Center for Research on the Epidemiology of Disasters. http://www.em-dat.net/disasters/Visualisation/emdat_var_chooser.php.

CRFM. 2006. Report of Second Annual Scientific Meeting – Port of Spain, Trinidad and Tobago, 13-22 March 2006. CRFM Fishery Report - 2006, Volume 1. 188 p.

CRFM. 2007. Report of Third Annual Scientific Meeting – Kingstown, St. Vincent and the Grenadines, 17-26 July 2007. Fishery Management Advisory Summaries. CRFM Fishery Report– 2007, Volume 2. 54 p.

CRFM 2008. CRFM Fishery Report -2008. Volume 1. Report of Fourth Annual Scientific Meeting – Kingstown, St. Vincent and the Grenadines, 10-20 June 2008. 221p.

CRFM 2009. CRFM Fishery Report - 2009. Volume 1. Report of Fifth Annual Scientific Meeting – Kingstown, St. Vincent and the Grenadines, 09-18 June 2009. 167p.

CFRAMP (2001). Report of the 2000 Caribbean Pelagic and Reef Fisheries Assessment and Management Workshop. CARICOM Fishery Report No. 9, 139 p.

CTO 2002

Dasgupta, T., and Perue, C. (2003). Toxicity Review for Agro-chemicals in St. Lucia and Jamaica. DFID NRSP Project R7668 (Report 3). July 2003. Chemistry Department, UWI, Mona, Jamaica.

Dawson JP (2002) Biogeography of azooxanthellate corals in the Caribbean and surrounding areas. Coral Reefs 21 (1): 27-40.

Delgado, G.A., R.A. Glazer, D. Hawtof, D. Aldana Aranda, L.A. Rodríguez-Gil, and A. de Jesús-Navarrete 2008. Do queen conch (*Strombus gigas*) larvae recruiting to the Florida Keys originate from upstream sources? Evidence from plankton and drifter studies. In: R. Grober-Dunsmore and B.D. Keller (Eds.) Caribbean Connectivity: Implications for Marine Protected Area Management. Marine Sanctuaries Conservation Series ONMS-08-07. Silver Spring: NOAA Office of National Marine Sanctuaries.

Diaz, R.J. and Rosenberg, R. (2008). Spreading dead zones and consequences for marine

Die, D. (2004). Status and assessment of large pelagic resources, p 15-44 in: Mahon, R. and McConney, P. (eds), Management of Large Pelagic Fisheries in CARICOM Countries. FAO Fish. Tech. Pap. 464. Ecosystems. Science, 321: 926-929.

Dow, W.E., K.L. Eckert, M. Palmer, P. and Kramer 2007. Sea turtle nesting habitat – A spatial database for the wider Caribbean region. WIDECAST Technical Report No. 6. Beaufort, North Carolina: Wider Caribbean Sea Turtle Conservation Network (WIDECAST) and The Nature Conservancy.

Ehrhardt, N. R. Puga and M. Butler IV. In press. The Caribbean spiny lobster, *Panulirus argus*, fisheries. In: Towards Marine Ecosystem-Based Management in the Wider Caribbean. L. Fanning, R. Mahon and P. McConney (eds). Report of Caribbean Regional Symposium, University of the West Indies, Cave Hill Campus, Barbados, December 10-12, 2008.

Fanning, L. P. and Oxenford, H.A. In press. Ecosystem Issues Pertaining to the Flyingfish (*Hirundichthys affinis*) Fisheries of the Eastern Caribbean, In: Towards Marine Ecosystem-Based Management in the Wider Caribbean. L. Fanning, R. Mahon and P. McConney, eds. Report of Caribbean Regional Symposium, University of the West Indies, Cave Hill Campus, Barbados, December 10-12, 2008.

Fanning, L., Mahon, R. and McConney, P. (Eds). Towards Marine Ecosystem-Based Management in the Wider Caribbean. Report of Caribbean Regional Symposium, University of the West Indies, Cave Hill Campus, Barbados, December 10-12, 2008. In press.

FAO 2000. FAO Annual Yearbook of Fisheries Statistics: Commodities, 2000. FAO, Rome.

FAO (2001a). Report of the FAO/DANIDA/CFRAMP/WECAFC regional workshop on the assessment of the Caribbean spiny lobster (*Panulirus argus*). Belize City, Belize 21 April – 2 May 1997 and Merida, Yucatan, Mexico 1-12 June 1998. FAO Fish. Report No. 619.

FAO (2001b). Report of the workshop on management of the Caribbean spiny lobster (Panulirus argus) fisheries in the area of the Western Central Atlantic Fishery Commission, Merida, Mexico 4-8 September 2000. FAO Fish. Report No. 643.

FAO (2002). Report of the second workshop on the management of Caribbean spiny lobster fisheries in the WECAFC area, Havana, Cuba, 30 September – 4 October 2002. FAO Fisheries Report No. 715.

FAO (2003a) Status and trends in mangrove area extent worldwide. Forest Resources Assessment Working Paper 63. Wilkie M, Fortuna S, eds. Forest Resources Division, FAO, Rome. http://www.fao.org/docrep/007/j1533e/j1533e00.htm.

FAO (2003b). The ecosystem approach to fisheries. FAO Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 2. Rome: Food and Agriculture Organization. 112 p.

FAO 2007. The world's mangroves 1980-2005. FAO Forestry Paper 153. FAO Rome

FAO 2008

FAO 2008. Western Central Atlantic Fishery Commission Report of the Third Meeting of the WECAFC Ad Hoc Flyingfish Working Group of the Eastern Caribbean. FAO Fisheries Report No. XXX, in press.

FAO 2009. Yearbook of fisheries and aquaculture statistics 2007. FAO, Rome

Fernandez, A., A. Singh and R. Jaffé 2007. A literature review on trace metals and organic compounds of anthropogenic origin in the Wider Caribbean Region. Mar. Poll. Bull. 54: 1681-1691.

FIINPESCA–OSPESCA/FAO/SUECIA 2009. Indicadores macroeconómicos del sector pesquero y acuícola del istmo centroamericano.Período 2000 – 2007. Octubre 2009. Proyecto “Plan de Apoyo a la Pesca en Centroamérica” PAPCA – OSPESCA / AECID / XUNTA DE GALICIA. Proyecto “Fortalecimiento de la investigación interdisciplinaria para la pesca responsable en los países centroamericanos” FIINPESCA – OSPESCA/FAO/SUECIA.

Fratantoni 2001

Gardner, T.A., Côté, I.M., Gill, J.A., Grant, A. and Watkinson, A.R. 2003. Long-term region-wide declines in Caribbean corals. Science 301: 958-960.

Garrison V. H., E. A. Shinn, W. T. Foreman, D.W. Griffin, and C.W. Holmes et al. 2003. African and Asian dust: from desert soils to coral reefs. *BioScience* **53**(5): 469–480.

Gelchu, A., Pauly, D. 2007. Growth and distribution of port-based global fishing effort within countries’ EEZs from 1970 to 1995. Fisheries Centre Research Reports 15(4). Fisheries Centre, University of British Columbia

George, S., S. Singh-Renton, and B. Lauckner. (2001). Assessment of Wahoo (*Acanthocybium solandri*) Fishery using Eastern Caribbean Data. Pp 25-40 In: CFRAMP. 2001. Report of the 2000 Caribbean Pelagic and Reef Fisheries Assessment and Management Workshop. CARICOM Fishery Report No. 9. 139 p.

GESAMP 2001. Protecting the oceans from land-based activities - Land-based sources and activities affecting the quality and uses of the marine, coastal and associated freshwater environment. GESAMP Reports and Studies 71.

GESAMP 2007, 2008

Gianni, M. and Simpson, W. 2005. The Changing Nature of High Seas Fishing: how flags of convenience provide cover for illegal, unreported and unregulated fishing. Australian Department of Agriculture, Fisheries and Forestry, International Transport Workers' Federation, and WWF International.

Gil-Agudelo, D.L. and Wells, P. G. In press. Impacts of Land-based Marine Pollution on Ecosystems in the Caribbean Sea. Implications to EBM approach in the Caribbean. In: Towards Marine Ecosystem-Based Management in the Wider Caribbean. L. Fanning, R. Mahon and P. McConney, eds.

Gilbes F, Armstrong R (2004) Phytoplankton dynamics in the eastern Caribbean Sea as detected with space remote sensing. Int J Remote Sens 25: 1449–1453.

Gracia, A., Medellín-Mora, J., Gil- Agudelo, D.L. y V. Puentes (eds.). 2009. Guía de las especies introducidas marino-costeras de Colombia. INVEMAR, Serie de Publicaciones Especiales No. 15 y Ministerio de Ambiente, Vivienda y Desarrollo Territorial. Bogotá, Colombia. 127 p.

Grober-Dunsmore, R., and B.D. Keller, eds. 2008. Caribbean connectivity: Implications for marine protected area management. Proceedings of a Special Symposium, 9-11 November 2006, 59th Annual Meeting of the Gulf and Caribbean Fisheries Institute, Belize City, Belize. Marine Sanctuaries Conservation Series ONMS-08-07. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 195 pp.

Guzmán, H.M. and E.M. García 2002. Mercury levels in corals along the Caribbean coast of Central America. Mar. Poll. Bull. 44(12): 1415-1420.

Gyory, J., A. J. Mariano, and E. H. Ryan. 2006. The Caribbean current. Ocean Surface Currents. http://oceancurrents.rsmas. miami.edu/caribbean/caribbean.html

Harbison GR, Janssen J (1987). Encounters with a Swordfish (*Xiphias gladius*) and Sharptail Mola (*Masturus lanceolatus*) at depths greater than 600 meters. Copeia 1987 (2): 511-513

Haugan et al 2006

Healthy Reefs for Healthy People 2010. Report card for the Mesoamerican Reef. An evaluation of ecosystem health. Healthy People Initiative, Smithsonian Institution, Belize City, Belize.

Heileman, S. in press. Ecosystem based fisheries management in the wider Caribbean: Deepwater red snapper fisheries. In: Towards Marine Ecosystem-Based Management in the Wider Caribbean. L. Fanning, R. Mahon and P. McConney (eds). Report of Caribbean Regional Symposium, University of the West Indies, Cave Hill Campus, Barbados, December 10-12, 2008.

Heileman, S. and Mahon, R. 2008. Wider Caribbean: Caribbean Sea LME, In Sherman, K. and Hempel, G. (eds) 2009. The UNEP Large Marine Ecosystem Report: A perspective on changing conditions in LMEs of the world's Regional Seas. UNEP Regional Seas Report and Studies No. 182. United Nations Environment Programme. Nairobi, Kenya.

Heileman, S., Mohammed, E. and Fanning, P. 2008. Derivation of diet compositions in the Lesser Antilles Pelagic Ecosystem. Technical Document No. 7 of Scientific Basis for Ecosystem-Based Management in the Lesser Antilles Including Interactions with Marine Mammals and Other Top Predators FAO. FI:GCP/RLA/140/JPN Barbados.

Heyman, W. D., and B. Kjerfve (1999) Hydrological and oceanographic considerations for integrated coastal zone management in southern Belize. Environ. Management, 24(2), 229-245.

Heyman, W., B. Kjerfve and T. Ezer. 2008. Mesoamerican reef spawning aggregation as sources: A review of the state of connectivity research and future priorities for science and management. Pages 150 -169 In Grober-Dunsmore, R., and B.D. Keller, eds. 2008. Caribbean connectivity: Implications for marine protected area management. Proceedings of a Special Symposium, 9-11 November 2006, 59th Annual Meeting of the Gulf and Caribbean Fisheries Institute, Belize City, Belize. Marine Sanctuaries Conservation Series ONMS-08-07. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 195 pp.

Heyman,W. D., Kjerfve, B., Graham, R.T., Rhodes, K.L. and Garbutt, L. 2005. Spawning aggregations of *Lutjanus cyanopterus* (Cuvier) on the Belize Barrier Reef over a 6 year period. Journal of Fish Biology 67:83–101.

Hoggarth, D.D., Sullivan, K. and Kimball, L. 2001. Latin America and the Caribbean Coastal and Marine Resources. Background paper prepared for GEO 3. UNEP Regional Office for Latin America and the Caribbean, Mexico, D.F.

Horrocks, J., Ward, N. and Haynes-Sutton, M. In press. An ecosystem-approach to fisheries: linkages with sea turtles, marine mammals and seabirds, in: Towards Marine Ecosystem-Based Management in the Wider Caribbean. L. Fanning, R. Mahon and P. McConney, eds.

http://www.chem.unep.ch/pts/regreports/Translated%20reports/Central%20America%20&%20Caribbean%20sp.pdf.

Huggins, A.E., S. Keel, P. Kramer, F. Núñez, S. Schill, R. Jeo, A. Chatwin, K. Thurlow, M. McPearson, M. Libby, R. Tingey, M. Palmer and R. Seybert 2007. Biodiversity Conservation Assessment of the Insular Caribbean Using the Caribbean Decision Support System, Summary Report, The Nature Conservancy.

Hughes, T.P., Maria J. Rodrigues, David R. Bellwood, Daniela Ceccarelli,Ove Hoegh-Guldberg, Laurence McCook, Natalie Moltschaniwskyj, Morgan S. Pratchett,, Robert S. Steneck and Bette Willis. 2007. Phase Shifts, Herbivory, and the Resilience of Coral Reefs to Climate Change. Current Biology 17, 360–365.

ICCAT (2001a). International Commission for the Conservation of Atlantic Tuna. Report for Biennial Period, 2000–2001, Part 1. Madrid, Spain.

ICCAT (2001b). International Commission for the Conservation of Atlantic Tuna. Report of the Fourth ICCAT Billfish Workshop. ICCAT Collective Volume of Scientific Papers 53:1-130.

ICCAT 2006. Report for biennial period, 2004-05 Part II (2005) - Vol. 2, Executive Summaries on Species: Small Tunas: 128-135.

ICCAT 2009. http://www.iccat.int/en/assess.htm

Idjadi, J.A. and Edmunds, P.J. (2006) Scleractinian corals as facilitators for other invertebrates on a Caribbean reef. Mar. Ecol. Prog. Ser. 319, 117–127.

IFDC/IFA/FAO. 1997. Survey of Fertilizer Rates of Use on the Individual Major World Crops.

INVEMAR 2001, 2007

IPCC (2001). Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

IPCC 2007. IPCC Fourth Assessment Report: Climate Change 2007 (AR4). M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds). Working Group II Report: "Impacts, Adaptation and Vulnerability". Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IUCN 2007. 2007 IUCN Red List of Threatened Species. Available at www.iucnredlist.org.

Jackson, J.B.C. (1997). Reefs since Columbus. Coral Reefs 16, S23–S32.

Jackson, J. B. C. et al. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293, 629–638.

Johns, W. E., T. L. Townsend, D. M. Fratantoni, and W. D. Wilson. 2002. On the Atlantic inflow to the Caribbean Sea. Deep-Sea Res. Part I. Oceanographic Res. Papers 49: 211–243.

Kairo, M.T.K., Ali, B., Cheesman, O., Haysom, K. and Murphy, S. (2003). Invasive Species Threats in the Caribbean Region. Report to the Nature Conservancy, Arlington, Virginia.

Kaly, U.L., Pratt, C.R. and Mitchell, J. (2004). The Demonstration Environmental Vulnerability Index (EVI) 2004. SOPAC Technical Report 384.

Kelleher, K. 2005. Discards in the world's marine fisheries. An update. FAO Fisheries Technical Paper. No. 470. Rome, FAO. 131p.

Khan, J.A. (2002). Status of the West Indian manatee in Trinidad and Tobago. Institute of Marine Affairs, Trinidad.

Kleisner, K. M. (2008). A spatiotemporal analysis of dolphinfish (Coryphaena hippurus), abundance in the western Atlantic and implications for stock assessment of a data-limited pelagic resource. PhD. Thesis. University of Miami. 343 p.

Kobara, S and Hayman, W. 2007. Caribbean-wide Geospatial Analysis of the location of transient reef fish spawning aggregation sites using remote sensing. Proceedings Gulf and Caribbean Fisheries Institute, 59: 397-400.

Koenig C.C., A.N. Shepard, J.K. Reed, F.C. Coleman, S.D. Brooke, J. Brusher and K.M. Scanlon 2005. Habitat and fish populations in the deep-sea *Oculina* coral ecosystem of the Western Atlantic. In: P.W. Barnes and J.P. Thomas (Eds.) Benthic Habitats and the Effects of Fishing. Pp 795-805 American Fisheries Society Symposium 41, Bethesda, MD,.

Kramer, P. (2003). Synthesis of Coral Reef Health Indicators for the Western Atlantic: Results of the AGGRA Programme (1997-2000), p. 1-57 in: Lang J.C. (ed), Status of Coral Reefs in the Western Atlantic: Results of Initial Surveys, Atlantic and Gulf Rapid Reef Assessment (AGRRA) Programme. Atoll Research Bulletin 496.

Lagueux, C.J. 2001. Status and Distribution of the Green Turtle, Chelonia mydas, in the Wider Caribbean Region. P. 32 -35 in: Eckert, K.L. and F. A. Abreu Grobois (eds.) 2001. Proceedings of the Regional Meeting: “Marine Turtle Conservation in the Wider Caribbean Region: A Dialogue for Effective Regional Management,” Santo Domingo, 16-18 November 1999. WIDECAST, IUCN-MTSG, WWF, and UNEP-CEP. xx + 154 pp

Lane and Stephenson 2000

Lankford, R. R. 1977. Coastal lagoons of Mexico their origin and classification. In: M. Wiley (Ed.), Estuarine processes, volume 2, circulation, sediments, and transfer of material in the estuary. *P*p. 182-215. *In*:. New York: Academic Press.

Leatherman, S. P. (1997). Beach ratings: a methodological approach. Journal of Coastal Research 13: 1050–1063.

Lee Lum, 2003

León, Y.M. and K.A. Bjorndal 2002. Selective feeding in the hawksbill turtle, an important predator in coral reef ecosystems. Marine Ecology Progress Series 245: 249-258.

Lessios, H. A., D. R. Robertson, and J. D. Cubit. 1984. Spread of the *Diadema* mass mortality through the Caribbean. *Science* 226(4672): 335–337.

Lessios, H.A., Garrido, M.J. and Kessing, B.D. (2001). Demographic history of *Diadema antillarum*, a keystone herbivore on Caribbean reefs. Proceedings of the Royal Society of London Series B-Biological Sciences 22, 268(1483):2347-2353.

Lewis, W.M. & J.F. Saunders. 1986) Chemistry of waters of the lower Orinoco River. In: “Ecosistema Orinoco”, Conocimiento actual y necesidades de futuros estudios. AsoVAC, 36: Convención Anual, Universidad de Carabobo, Valencia. Venezuela, 345-349.

Lopez, V. and U. Krauss. 2006. National and Regional Capacities and Experience on Marine Invasive Species, Including Ballast Waters, Management Programmes in the

Wider Caribbean Region. A compilation of Current Information. UNEP and CAB International.

Lutz, S. J. and R. N. Ginsburg. 2007. The State of Deep Coral Ecosystems of the United States. (NOAA Technical Memorandum CRCP-3). US Department of Commerce - National Oceanic and Atmospheric Administration. 1–59.

Mahon, R. (1990). Fishery management options for Lesser Antilles countries. FAO Fish. Tech. Paper No. 313.

Mahon, R. (1993). Marine Fishery Resources of the Antilles: Lesser Antilles, Puerto Rico and Hispanola, Jamaica, Cuba. FAO Fish. Tech. Pap. No. 326.

Mahon, R. 1999. Dolphinfish fisheries in the Caribbean Region. Sci. Mar. 63 (3-4): 411-420.

Mahon, R. (2002a). Living Aquatic Resource Management, p 143-218 in: Goodbody, I. and Thomas-Hope, E. (eds), Natural Resource Management for Sustainable Development in the Caribbean. Canoe Press, UWI, Kingston, Jamaica.

Mahon, R. 2002b. Adaptation of Fisheries and Fishing Communities to the Impacts of Climate Change in the CARICOM Region. Issues paper prepared for the CARICOM Fisheries Unit, Belize City, Belize, as input to the planning process for the project Mainstreaming Adaptation to Climate Change (MACC) of the Caribbean Centre for Climate Change (CCCC).

Mahon 2004

Mahon, R. and McConney, P.A. (eds.) (2004). Management of large pelagic fisheries in CARICOM countries. FAO Fisheries Technical Paper. No. 464.

Mahon, R., C. Parker, T. Sinckler, S. Willoughby, and J. Johnson 2007. The Value of Barbados Fisheries: A Preliminary Assessment. Fisheries Division, Ministry of Agriculture and Rural Development, Barbados, Fisheries Management Plan Public Information Document No. 2. 24pp.

Mahon, R., McConney, P. and Roy, R. (2008). Governing fisheries as complex adaptive systems. Marine Policy 32:104–12.

Mahon, R., L. Fanning and P. McConney. 2009. A governance perspective on the large marine ecosystem approach. Marine Policy 33 (2009) 317–321.

Manooch, C.S., III. 1987. Age and growth of snappers and groupers. In: J.J. Polovina and S. Ralston (Eds.) Tropical snappers and groupers: biology and fisheries management. P. 329-373. Ocean Resour. Mar. Policy Ser. Westview Press, Inc., Boulder and London.

Martinelli et al 2006

McClenachan, L., Jackson, J. B. C. and Marah J. H. Newman. 2006. Conservation Implications of Historic Sea Turtle Nesting Beach Loss. Frontiers in Ecology and the Environment 4 (6): 290-296. McLean et al 2001

McConney, P. A. (2004). National management and development of large pelagic fisheries, p. 87 – 106, in: Mahon, R. and McConney, P.A. (eds.), Management of large pelagic fisheries in CARICOM countries. FAO Fisheries Technical Paper. No. 464.

McElroy, J. L. 2004. Global perspectives of Caribbean tourism. Pages 39–56. In D. Duval, ed. Tourism in the Caribbean: Trends, developments, prospects. London, G.B.: Taylor and Francis Group.

Melvin G., P. Fanning, C. O'Donnell, M. Dahl, L. Edwards, R. Gardner, H. Simon and D. Theophille. 2007. Scientific Basis for Ecosystem-Based Management in the Lesser Antilles including Interactions with Marine Mammals and Other Top Predators: Acoustic biomass estimates of pelagic forage species in the offshore waters of the Lesser Antilles. FI:GCP/RLA/140/JPN Technical Document No. 6. FAO, Barbados.

Meybeck, M. 1982. Carbon, nitrogen and phosphorus transport by World Rivers. Report. Am J. Sciense. 282, 401-450.

Millennium Ecosystem Assessment 2005. Ecosystems and human well-being: A framework for assessment. Millennium Ecosystem Assessment, Washington, D.C.: Island Press.

Miloslavich P, Dıaz JM, Klein E, Alvarado JJ, Dıaz C, et al. (2010) Marine Biodiversity in the Caribbean: Regional Estimates and Distribution Patterns. PLoS ONE 5(8): e11916. doi:10.1371/journal.pone.0011916

Mittermeier, R.A., Myers, N. and Mittermeier, C.G. 2000. Hotspots: Earth's biologically richest and most endangered terrestrial ecoregions. Conservation International Publications.

MOHA (Ministry of Home Affairs, Maldives), 2001: First National Communication of the Republic of Maldives to the United Nations Framework Convention on Climate Change, Ministry of Home Affairs, Housing and Environment, Malé, Republic of Maldives.

Mohammed, E. 2003. Reconstructing fisheries catches and fishing effort for the southeastern Caribbean (1940– 2001): General methodology. P. 11–20. *In* D. Zeller, S. Booth, E. Mohammed, and D. Pauly, eds. From Mexico to Brazil: Central Atlantic Fisheries catch trends and ecosystem models. Fish. Centre Res. Rep. Vol. 11, No. 6.

Mohammed et al 2003

Mohammed et al 2007

Mohammed, E., Vasconcellos, M., Mackinson, S., Fanning, P., Heileman, S. and Carocci, F. 2008. A trophic model of the Lesser Antilles Pelagic ecosystem. Report prepared for the Lesser Antilles Pelagic Ecosystem Project (GCP/RLA/140/JPN), Scientific basis for ecosystem-based Management in the Lesser Antilles including Interactions with marine mammals and other Top predators: Assessment of fisheries management issues In the Lesser Antilles and the ecosystem approach to fisheries management.

Molinari, R.L., Spillane, M., Brooks, I., Atwood, D. and Duckett, C. (1981). Surface current in the Caribbean Sea as deduced from Lagrangian observations. Journal of Geophysical Research 86: 6537-6542.

Mora, C. and P. Sale. 2002. Are populations of coral reef fish open or closed? Trends in Ecology and Evolution 17: 422-428.

Muller-Karger, F. E., C. R. McClain, and P. L. Richardson. 1988. The dispersal of the Amazon's water. Nature 333: 56–59.

Müller Karger, F. E., C. R. McClain, T. R. Fisher, W. E. Esaias and R. Varela. 1989. Pigment distribution in the Caribbean Sea: Observations from space. *Prog. Oceanogr*. 23: 23–64.

Muller-Karger FE, Castro RA (1994) Mesoscale processes affecting phytoplankton abundance in the southern Caribbean Sea. Cont Shelf Res 14: 199–221.

Mumby, P. 2006a. Connectivity of reef fish between mangroves and coral reefs: Algorithms for the design of marine reserves at seascape scales. Biological Conservation 128: 215- 222.

Mumby, P. 2006b. The impact of exploiting grazers (scaridae) on the dynamics of Caribbean coral reefs. Ecological Applications, 16(2), 2006, pp. 747–769

Mumby PJ, Edwards AJ, Arias-Gonzalez EJ, Lindeman KC, Blackwell PG, Gall A, Gorczynska MI, Harborne AR, Pescod CL, Renken H, Wabnitz CCC, Llewellyn G (2004) Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature 427:533–536.

Mumby, P.J. and Hastings, A. (2008). The impact of ecosystem connectivity on coral reef resilience. J Appl Ecol 45: 854–862.

Mumby, P. J., C. P. Dahlgren, A. R. Harborne, C. V. Kappel, F. Micheli, D. R. Brumbaugh, K. E. Holmes, J. M. Mendes, K. Broad, J. N. Sanchirico, K. Buch, S. Box, R. W. Stoffle, and A. B. Gill. 2006. Fishing, trophic cascades, and the process of grazing on coral reefs. *Science* 311(5757):98–101.

Mumby, P.J. and R. S. Steneck. 2008. Coral reef management and conservation in light of rapidly evolving ecological paradigms. Recruitment in degraded marine habitats: a spatially explicit, individual-based model for spiny lobsters. Ecol Appl 15:902–918.

Munday, P.L. (2004) Habitat loss, resource specialization, and extinction on coral reefs. Glob. Change Biol. 10, 1642–1647

Munday, P. L., J. M. Leis, J. M. Lough, C. B. Paris, M. J. Kingsford, M. L. Berumen and J. Lambrechts. 2009. Climate change and coral reef connectivity. Coral Reefs. Review published online. Springer-Verlag 2009.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. Nature 403: 853-858.

Myers, R. A. and Worm, B. 2003. Rapid worldwide depletion of predatory fish communities. Nature 423, 280-283.

National Weather Service/Climate Prediction Center (2007) Cold and warm episodes by seasons [3 month running mean of SST anomalies in the Niño 3.4 region (5oN-5oS, 120o-170oW)][based on the 1971-2000 base period], www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

Nemeth, R.S., E. Kadison, J. E. Blondeau, N. Idrisi, R. Watlington, K. Brown, T. Smith, and L. Carr 2008. Regional Coupling of Red Hind Spawning Aggregations to Oceanographic Processes in the Eastern Caribbean, pages 170 -183 in In Grober-Dunsmore, R., and B.D. Keller, eds. 2008. Caribbean connectivity: Implications for marine protected area management. Proceedings of a Special Symposium, 9-11 November 2006, 59th Annual Meeting of the Gulf and Caribbean Fisheries Institute, Belize City, Belize. Marine Sanctuaries Conservation Series ONMS-08-07. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 195 pp.

NOAA (2003). LME 12 Caribbean Sea. http://na.nefsc.noaa.gov/lme/text/lme12.htm

NOAA (2008). Ocean Acidification in the Caribbean Significant, Yet Variable. ScienceDaily. Retrieved December 20, 2010, from http://www.sciencedaily.com /releases/2008/11/081121163353.htm

Oxenford, H.A., R. Mahon and W. Hunte (eds) 1993. The Eastern Caribbean Flyingfish Project. OECS Fishery Report No. 9, 171 pp.

Oxenford, H. A. and W. Hunte 1999. Feeding habits of the dolphinfish (*Coryphaena hippurus*) in the eastern Caribbean. Scientia Marina 63(3-4):303-315.

Oxenford, H.A., R. Mahon and W. Hunte 2007 (eds). The Biology and Management of Eastern Caribbean Flyingfish. Centre for Resource Management and Environmental Studies, University of the West Indies, Barbados, 267pp.

Paddack, M.J. and others. 2009. Recent Region-wide Declines in Caribbean Reef Fish Abundance. Current Biology 19, 590–595.

Pandolfi et al. 2003

Paris, C.B., R.K. Cowen, R. Claro, K.C. Lindeman. 2005. Larval transport pathways from Cuban snapper (Lutjanidae) spawning aggregations based on biophysical modeling. Mar. Ecol. Prog. Ser. 296: 93-106

Parker et al 2000

Pattullo 1998 in Ocean Conservancy 2002

Pauly et al 2005

Pauly D, Christensen V, Dalsgaard J, Froese R, Torres F (1998). Fishing down marine food webs. Science 279(5352): 860–863.

Pelagic Fisheries Conservation Program 2006. Bioaccumulation of mercury in pelagic fishes of the Gulf of Mexico. Texas A & M University at Galveston. http://www.tamug.edu/pelagic/Mercury-study.htm

PNUMA 2007

Polidoro BA, Carpenter KE, Collins L, Duke NC, Ellison AM, et al. (2010). The Loss of Species: Mangrove Extinction Risk and Geographic Areas of Global Concern. PLoS ONE 5(4): e10095. doi:10.1371/journal.pone.0010095

Prada, M, G. Peñaloza, S.Posada, N.Howard, P.Herron, L. Salinas, E. Castro, F. Cabezas, and H. Robinson. 2004. Fish spawning aggregations in the San Andres archipelago, a first approximation. Technical Report TOC-CORALINA. San Andres Isla Colombia. 50 pp.

Prada, M., E. Castro, E. Puello, M. Pomare, G. Penaloza, L. James And H. Robinson. 2007. Threats to the grouper population due to fishing during reproductive seasons in the San Andres and Providencia Archipelago, Colombia. Proc. Gulf and Caribbean Fisheries Institute, 58: 270 -275.

Precht, W. F. 2002. Endangered Acroporid Corals of theCaribbean. *Coral Reefs* 21: 41–42.

Puentes Granada, V. 2011. Revisión y análisis de las capturas incidentales: hacia la aplicación del enfoque ecosistemico en el manejo sostenible de las pesquerías de Colombia. Documento Técnico, Ministerio de Ambiente Vivienda y Desarrollo Territorial. In press.

Puga, R., R. Piñeiro, N. Capetillo, M.E. de León and L.S. Cobas 2008. Estado de la pesquería de langosta espinosa (*P. argus*) y su relación con factores ambientales y antrópicos en Cuba. Informe de Caso de Estudio del Programa: PNCT: Los cambios Globales y la Evolución del Medio Ambiente Cubano. Proyecto: Bases Oceanográficas para el estudio de las afectaciones del cambio global en la biodiversidad marina y costera de Cuba. Tarea: Evaluación de las posibles afectaciones del Cambio Climático a la Biodiversidad Marina y Costera de Cuba. Havana: Centro de Investigaciones Pesqueras. Septiembre de 2008.

Ramirez, A., A.W. Rose and C. Bifano (1988). Transport of carbon and nutrients by the Tuy River, Venezuela. Mitt. Geol. Palaont. Inst., Univ. Hamburg. SCOPE/UNEP Sonderband Heft 66. 137-146.

Raven et al 2005

Reed JK (2002). Comparison of deep-water coral reefs and lithoherms off southeastern U.S.A. Hydrobiologia 471: 43-55

Restrepo, J. D., and B. Kjerfve. 2000. Magdalena River: Interannual variability (1975–1995) and revised water discharge and sediment load estimates. J. Hydrol. 235: 137–149.

Restrepo, J. D., P. Zapata, J. M. Diaz, J. Garzon, and C. Garcia. 2005. Fluvial fluxes into the Caribbean Sea and their impact on coastal ecosystems: the Magdalena River, Colombia. Global and Planetary Change 50: 33–49.

Reyes J, Santodomingo N, Gracia A, Borrero-Pérez G, Navas G, Ladino LM, Bermúdez A, Benavides M (2005). Southern Caribbean azooxanthellate coral communities off Colombia. In: Freiwald A, Roberts J (Eds) Cold-water Corals and Ecosystems Proceedings of the 2nd International Symposium on Deep-Sea Corals Sept. 9-12 2003 Erlanger Germany.

Reynal et al. 2006

Rice, D.W. (1973). Caribbean monk seal (*Monachus tropicalis*), p. 98-112: in K. Ronald, (ed), Seals: Proceedings of a working meeting of seal specialists on threatened and depleted seals of the world, held under the auspices of the Survival Service Commission of the IUCN, IUCN Supplementary Paper 39.

Richardson, A.J. and Schoeman, D.S. 2004. Climate impact on plankton ecosystems in the Northeast Atlantic. Science 305, 1609–1612.

Rojas Galavíz, J. L., A. Yáñez-Arancibia, J. W. Day and R. Vera-Herrera 1992. Estuarine primary producers. In: U. Seeliger (Ed.), Coastal plant communities of Latin America. P. 141-154. , San Diego: Academic Press Inc.

Ross, S.W. and M.S. Nizinski 2007. State of Deep Coral Ecosystems in the Southeast Region: Cape Hatteras to Southeast Florida. In: SE Lumsden, TF Hourigan, AW Bruckner and G Dorr (eds.) The State of Deep Coral Ecosystems of the United States. P. 233-269. NOAA Technical Memorandum CRCP-3, Silver Spring, Maryland.

Rylander, K., J. Perez, and J. A. Gomez. 1996. Status of the green mussel, *Perna viridis* (Linneaus 1758) (Mollusca: Mytilidae), in north-eastern Venezuela. Caribbean Marine Studies 5:86-87.

Sadovy, Y. (1994). Grouper stocks of the western central Atlantic: the need for management and management needs. Proceedings of the Gulf and Caribbean Fisheries Institute 43, 43-64.

Sadovy, Y. and Eklund, A.M. (1999). Synopsis of biological data on the Nassau grouper, *Epinephelus striatus* (Bloch, 1792) and the Jewfish, *E. itijara* (Lichtenstein, 1822). U.S. Dep. Commer., NOAA Technical Report NMFS 146.

Sala et al. 2001

Salas Serrano, J. 2007. Vulnerabilidad, pobreza y desastres ´socionaturales´ en Centroamérica y El Caribe. Informes de la Construcción 59 (508), 29-41.

Sandt, V.J. and A.W. Stoner 1993. Ontogenetic shift in habitat by early juvenile queen conch, *Strombus gigas*: patterns and potential mechanisms. Fishery Bulletin 91(3): 516-525.

Santodomingo N, Reyes J, Gracia A, Martínez A, Ojeda G, García G (2006) Madracis coral communities off San Bernardo Islands (Colombian Caribbean). Bulletin of Marine Science, *in press*, manuscript received November 2006, 29 pp

Sea Around Us Project. 2010. Large Marine Ecosystems. University of British Colombia Fisheries Center, Canada. http://www.seaaroundus.org/lme/

Sealey, S. K. and Bustamente, G. (1999) Setting geographic priorities for marine conservation in Latin America and the Caribbean. Arlington, Virginia. US. The Nature Conservancy. 125 p.

Sedberry G.R., Stevenson D.E. and Chapman R.W. 1996. Stock identification in potentially threatened species of grouper (Teleostei: Serranidae: Epinephelinae) in Atlantic and Caribbean waters. South Carolina Department of Natural Resources, Marine Resources Research Institute.

Seitzinger, S. and Lee, R. 2008. Land-based Nutrient Loading to LMEs: A Global Watershed Perspective on Magnitudes and Sources. In Sherman, K. and Hempel, G.

(Editors) 2009. The UNEP Large Marine Ecosystem Report: A perspective on changing conditions in LMEs of the world's Regional Seas. UNEP Regional Seas Report and Studies No. 182. United Nations Environment Programme. Nairobi, Kenya.

Selman, M., Greenhalgh, S., Diaz, R. and Sugg, Z. 2008. Eutrophication and hypoxia in coastal areas: A global assessment of the state of knowledge. World Resources Institute Policy Note, Water Quality: Eutrophication and Hypoxia 1.

Sherman, K., I. M. Belkin, K. D. Friedland, J. O'Reilly and K. Hyde. 2009. Accelerated Warming and Emergent Trends in Fisheries Biomass Yields of the World's Large Marine Ecosystems. Ambio Vol. 38, No. 4, 215– 224.

SICA 2011. Turistas en Centroamerica por nacionalidad año 2006. Estadísticas Turísticas Centroamericanas, http://www.sica.int/cct/estadisticas.aspx?IdEnt=11

Silberman, J., Sarver, S. and Walsh, P. (1994). Mitochondrial DNA variation and population structure in the spiny lobster *Panulirus argus*. Marine Biology 120: 601-608.

Singh-Renton, S, D. J. Die and E. Mohammed. In press. An Ecosystem Approach to Fisheries (EAF) for Management of Large Pelagic Fish Resources in the Caribbean Large Marine Ecosystem, In: Towards Marine Ecosystem-Based Management in the Wider Caribbean. L. Fanning, R. Mahon and P. McConney, eds.

Smith, B. E. 2010. Population and Urbanization in Latin America and the Caribbean. Geographische Rundschau International Edition Vol. 6, No 3: 30 -34.

Smith, A.H. *et al*. (2000). Status of the Coral Reefs in the Eastern Caribbean: The OECS; Trinidad and Tobago, Barbados, The Netherlands Antilles and the French Caribbean. In Wilkinson, C. (ed), Status of Coral Reefs of the World 2000. Australian Institute of Marine Sciences (AIMS) Australia.

Spalding, M. D., and A. M. Greenfeel. 1997. New estimate of global and regional coral reef areas. *Coral Reefs* 16: 225–230.

Spalding, M.D. (2004). Guide to the coral reefs of the Caribbean. University of California Press, Berkeley, California.

Staskiewicz, T., J.Walcott, H. A. Oxenford and P.W. Schuhmann 2008. Analysis of the fisheries landings, vessel and demographic data collected by the Government of Barbados. Report for the Barbados Fisheries Division, Ministry of Agriculture and Rural Development, Barbados, 36pp.

Steneck, R. S. 1994. Is herbivore loss more damaging to reefs than hurricanes? Case studies from two Caribbean reef systems (1978–1988). Pages C32–C37 in R. N. Ginsburg, editor. Global aspects of coral reefs: health, hazards, and history. University of Miami, Miami, Florida, USA.

Steneck, R. S., C. B. Paris, S. N. Arnold, M. C. Ablan-Lagman, A. C. Alcala, M. J. Butler, L. J. McCook, G. R. Russ and P. F. Sale. 2009. Thinking and managing outside the box: coalescing connectivity networks to build region-wide resilience in coral reef ecosystems. Coral Reefs, review.

Sumaila, U.R. and Pauly, D. (eds). 2006. Catching more bait: a bottom-up re-estimation of global fisheries subsidies (2nd Version). Fisheries Centre Research Reports 14(6), pp. 2. Fisheries Centre, the University of British Columbia, Vancouver, Canada.

Sweeney, V. and Corbin, C. In press. Implications of Land-Based Activities in Small Islands for Marine EBM. In: Towards Marine Ecosystem-Based Management in the Wider Caribbean. L. Fanning, R. Mahon and P. McConney, eds.

Taquet, M, Reynal, L., Laurans, M., Lagina, A. (2000). Blackfin tuna (*Thunnus atlanticus*) fishing around FADs in Martinique (French West Indies). Aquat. Living Resour. 13. 259−262.

Trotz, A. 2003. Women and Poverty in the Caribbean, paper prepared for the ECLAC/CDCC/UNIFEM/CIDA/ CARICOM Fourth Ministerial Caribbean Conference on Women, February 2003, Saint Vincent and the Grenadines.

UN DESA (2009). "World Population Prospects: The 2008 Revision". New York: Department for Economic and Social Affairs.

UNDP (2006). Human Development Report 2006. United Nations Development Programme, NY. http://hdr.undp.org/hdr2006/statistics/

UN-ECLAC 2007

UN-ECLAC 2010. Statistical Yearbook for Latin America and the Caribbean. UN-ECLAC, Santiago, Chile

UN Habitat 2008. State of the World's Cities 2008/2009. Harmonious Cities. Earthscan, London, Sterling, VA.

UNEP (2000). GEO Latin America and Caribbean: Environment Outlook 2000. UNEP Regional Office for Latin America and the Caribbean, Mexico, D.F.

UNEP 2003

UNEP (2004a). Bernal, M.C., Londoño, L.M., Troncoso, W., Sierra- Correa, P.C. and Arias-Isaza, F.A. Caribbean Sea/Small Islands, GIWA Regional Assessment 3a. University of Kalmar, Kalmar, Sweden. http://www.giwa.net/publications/r3a.phtml.

UNEP (2004b). Villasol, A. and Beltrán, J. Caribbean Islands, GIWA Regional Assessement 4. Fortnam, M. and Blime P. (eds), University of Kalmar, Kalmar, Sweden. http://www.giwa.net/publications/r4.phtml

UNEP (2006). Isaza, C.F.A., Sierra-Correa, P.C., Bernal-Velasquez, M., Londoño, L.M. and W. Troncoso. Caribbean Sea/Colombia & Venezuela, Caribbean Sea/Central America & Mexico, GIWA Regional assessment 3b, 3c. University of Kalmar, Kalmar, Sweden.

UNEP 2005. Caribbean Environmental Outlook. UNEP, Nairobi, Kenya.

UNEP-RCU/CEP (1997). Coastal Tourism in the Wider Caribbean Region: Impacts and best management practices. CEP Technical Report No. 38. UNEP Caribbean Environment Programme, Kingston, Jamaica.

UNEP-RCU/CEP (1998). An overview of land-based sources of marine pollution. CEP Technical Report No. 40. UNEP Caribbean Environment Programme, Kingston, Jamaica.

UNEP-RCU/CEP (2001). Elements for the development of a marine mammal action plan for the Wider Caribbean: A Review of marine mammal distribution. UNEP Caribbean Environment Programme, Kingston, Jamaica.

UNEP-RCU/CEP. 2010. Land-based Sources and Activities in the Wider Caribbean Region. Updated CEP Technical Report No. 33.

UNEP-RCU/CEP 2011. UNEP Regional Seas Marine Biodiversity Assessment and Outlook Series: Wider Caribbean Region. UNEP Jamaica.

UNEP-RCU/CEP/Cimab 2010. Programme for monitoring the quality of marine ecosystems in high-risk areas in the Wider Caribbean Region. Final report. Regional project: "Regional Network in Marine Science and Technology for the Caribbean: *Know-Why Network*". UNEP-CEP, Kingston, Jamaica and Cimab, Havana, Cuba. 62 pgs.

UNEP/GEF (2002). Evaluación Regional Sobre Sustancias Tóxicas Persistentes. Informe Regional De América Central y El Caribe.

Upadhyay VP, Ranjan R, Singh JS (2002) Human-mangrove conflicts: The way out. Curr Sci India 83: 1328–1336

USGS (2000). African dust causes widespread environmental distress. http://coastal.er.usgs.gov/african_dust/dust-infosheet.pdf

Vila, L. et al. 2004. Estudio sobre el tráfico marítimo en torno a la República de Cuba. Informe Técnico. Centro de Investigaciones del Transporte (Cetra), La Habana. 61p

Ward-Paige CA, Mora C, Lotze HK, Pattengill-Semmens C, McClenachan L, et al. (2010) Large-Scale Absence of Sharks on Reefs in the Greater-Caribbean: A Footprint of Human Pressures. PLoS ONE 5(8): e11968. doi:10.1371/journal.pone.0011968

Webber, D. and Clarke, T. (2002). Environmental overview of Kingston Harbour, Jamaica, p. 42-52: in Caribbean Basins: LOICZ Global Change Assessment and Synthesis of River Catchment/Island-Coastal Sea Interactions and Human Dimensions; with a desktop study of Oceania Basins. LOICZ Reports and Studies 27, Texel, The Netherlands.

WECAFC 2003

Wege, D. 2005. Building on Caribbean bird conservation efforts through the integration of migratory bird initiatives: A step closer to "all-bird" conservation. *J. Carib. Ornithol.* 18:99-100.

Wielgus, J., E. Cooper, R. Torres and L. Burke. 2010. Coastal Capital: Dominican Republic. Case studies on the economic value of coastal ecosystems in the Dominican Republic. Working Paper. Washington, DC: World Resources Institute. Available online at http://www.wri.org/coastal-capital.

Wilkinson, C. (ed). (2000). Status of Coral Reefs of the World: 2000. Australian Institute of Marine Science. Australia.

Wilkinson, C. (ed). (2002). Status of Coral Reefs of the World: 2002. Australian Institute of Marine Sciences, Townsville, Queensland, Australia.

Wilkinson, C. and Souter, D. (2008). Status of Caribbean coral reefs after bleaching and hurricanes in 2005. Global Coral Reef Monitoring Network, and Reef and Rainforest Research Centre, Townsville, 152 p.

Woodley, J., *et al*. (2000). Status of Coral Reefs in the Northern Caribbean and Western Atlantic. In: Wilkinson, C. (ed). Status of Coral Reefs of the World: 2000. Australian Institute of Marine Science, Australia.

World Bank (2000). Small States: Meeting challenges in the global economy. Report of the Commonwealth Secretariat/World Bank Joint Task Force on Small States. World Bank, Washington, DC.

Worm, B. et al. 2006. Impacts of Biodiversity Loss on Ocean Ecosystem Services. Science 314: 787- 790.

WRI 2006. Watershed Analysis for the Mesoamerican Reef. World Resources Institute. Washington, D.C.

WRI 2009. Value of Coral Reefs & Mangroves in the Caribbean -- Economic Valuation Methodology V3.0. World Resources Institute, January 2009.

Wynne, S.P. and Cote, I.M. (2007) Effects ofhabitat quality and fishing on Caribbean spotted spiny lobster populations. J. Appl. Ecol. 44, 488–494

Zollett, E.A. 2009. Bycatch of protected species and other species of concern in US east coast commercial fisheries. Endangered Species Research Vol. 9: 49–59.

ANNEXES

Annex 1. Summary of the major differences between the thematic reports and current TDAs

Component	2007 Thematic reports	2011 Reef and Pelagic Ecosystems TDAs
Geographic coverage	• Insular Caribbean • Central/South America (separately)	Reef and pelagic fisheries ecosystems throughout the entire CLME region
Ecosystems	CLME, with reef and pelagic systems combined	Separate TDAs for reef and pelagic ecosystems (as far as data and information were available for each of the two systems individually)
Description of the CLME	General overview	Detailed description of global and transboundary significance of the CLME, its political and oceanographic features
Ecology and biodiversity	General overview of ecology and biodiversity	Detailed description of reef and pelagic systems- habitats, major living marine resources (fish, invertebrates, marine turtles, marine mammals, whale shark, migratory birds and other groups), detailed description of the regional and global significance of CLME ecosystems and biodiversity, including unique features of the CLME. This also includes recent information from the Census of Marine Life Caribbean programme
Socio-economic background	Socio-economic indicators by country, general description of socio-economic features, SIDs vulnerability, overview of natural disasters	Updated socio-economic indicators, urbanization trends and implications for coastal areas and populations, impacts of natural disasters (including recent ones), major economic sectors, detailed description of fisheries and tourism sectors (comparison of fisheries and tourism contribution to GDP, numbers employed, number of boats, fish protein consumption) with some statistics at country level
Ecosystem approach	Recommended as a suitable approach for managing the CLME living resources and habitats, but underscored the need for more information	Tries to incorporate the ecosystem approach in the analyses, taking a holistic view of the two ecosystems as well as linkages between them. Since the 2007 reports, major initiatives in EAF/EBM have taken place in the region (e.g. 2007 ecological assessment of the Caribbean Sea, 2008 symposium on marine EBM in the wider Caribbean, 2008 LAPE project), which have provided valuable information for the current TDAs

Ecosystem services	No particular focus, although mentioned where appropriate	Comprehensive list of ecosystem services for each of the two ecosystems based on the Millennium Ecosystem Assessment, with economic value of the major reef ecosystem services (including in three CLME countries) estimated by WRI included. Human dependence on ecosystem services and impacts of the three priority issues on ecosystem services
Unsustainable exploitation	Brief description of environmental and socio-economic impacts; Description of major fisheries resources, trends in fish landings, mean trophic level and FiB index for reef and pelagic species combined for the Insular Caribbean only, brief mention of fish spawning aggregations; description of deep water reef habitats not included	Updated and more detailed description of the major transboundary resources and fisheries for each ecosystem, including of deep water reef habitats and of large pelagic species of particular interest for CLME countries; updated trends (1950 to 2006) in fish landings, value, mean trophic level and FiB Index for reef and pelagic fisheries separately; a new fisheries indicator (stock status plots) that shows number of collapsed reef and pelagic fish stocks in the CLME – these plots provide a holistic picture of the status of the region's reef ad pelagic resources, and confirm widespread reports of decling fish stock throughout the region. The mean trophic level, FiB index and catch-stock status plots are very important indicators of the ecosystem effects of fishing, and are usually produced by the University of British Colombia for reef and pelagic stocks combined for each LME. For the current TDAs, the University of British Colombia prepared these analyses for reef and pelagic stocks separately for the CLME project. The current TDAs also include more detailed analysis of specific resources and status of the fisheries, including turtles and marine mammals; incorporation of EAF/EBM information; more in-depth assessment of reef fish spawning aggregations; impact of overfishing of herbivores on reef health and resilience; and flags of convenience
Habitat degradation	Description of environmental and socio-economic impacts with focus on coral reefs (good level of detail to show general trends), limited discussion of other coastal habitats, pelagic habitat, deepwater reefs; brief mention of impacts of global warming; no explicit discussion of the importance of demographic	Detailed analysis of habitats – particularly reef and mangrove- based on updated information (e.g. Reefs at Risk revisited, a 2011 update of the 2004 Reefs at Risk threat index in the Caribbean, recent information on global warming, increased SST and impacts on corals in the Caribbean, impacts of rising SST on fish stocks, ecoregional assessment of MesoAmerican Reef); also separate analysis of the three issues in the pelagic ecosystem; assessment of vulnerability of certain countries to reef loss and economic cost of reef loss; review of vast literature on connectivity and discussion of connectivity among marine habitats and spawning populations and settlement areas, and implications for reef resilience and management of living marine resources; invasive species (red lion fish and green mussel); recent data and

	connectivity in marine ecosystems	information on region-wide status and extent of Caribbean reefs and mangroves (latter at country level); discussion of algal overgrowth of corals including impacts of overfishing of reef herbivores
Pollution	Assessment of main pollutants, sources and environmental and socio-economic impacts; limited data on pollution loads from different sources; analysis not conducted separately for reef and pelagic ecosystems	Concrete data and information on pollution loads, ship traffic, wastewater discharge, etc. Since the 2007 report, a number of studies have become available that provide data on pollution loads from various sources (e.g. Update of the 1998 report from UNEP-CAR/RCU on landbased sources of pollution in the WCR including a comparative analysis with the 1998 report; analysis of WRI on nutrient and sediment loads to the Mesoamerican Reef; ballast water disposal); separate analysis of pollution for reef and pelagic ecosystems
Causal chain analysis	Both reports included fairly good coverage of the causal chains for the three issues, which consisted primarily of lists of the major causes	The CCAs were reoriented for the reef and pelagic ecosystems. The CCA statements developed by the TTT under the full size project were grouped under a number of categories and validated with available information in a more narrative form, making reference to the TDAs for the three isues. A difficulty encountered in some cases was the unavailability of information separately for reef and pelagic systems. There was much overlap in the various causes and impacts on the two ecosystems wit no clear separation in many instances.
Proposed interventions	Both reports provided a comprehensive list of proposed options to address the three issues	The current report acknowledges that a wide array of options as well as of regional and international policy framework exists and recommends that these be implemented at the national levels. The report highlights a few options and defers a more in depth evaluation and prioritization for the SAP phase.
Governance and stakeholder analysis	Included in the 2007 reports	A separate governance and stakeholder analysis was undertaken under the full size project. In the reef and pelagic ecosystems TDAs, however, relevant policy frameworks are mentioned as appropriate.

Annex 2. Domestic pollutant loads (tonnes.yr^{-1}) discharged by country and sub-region in WCR (up until 2009)

(UNEP-RCU/CEP 2010)

Country/territory	BOD_5	COD	TSS	TN	TP
Sub-region II					
Belize	813	1,875	791	100	37
Guatemala	640	1,455	582	70	23
Honduras	2,558	5,815	2,329	280	93
Nicaragua	395	898	359	43	14
Costa Rica	984	2,237	895	107	36
Panama	9,099	20,747	8,397	1,019	349
Subtotal	***14,489***	***33,027***	***13,353***	***1,619***	***552***
Sub-region III					
Colombia	20,193	46,236	18,996	2,339	830
Venezuela	83,649	192,218	79,977	9,968	3,631
Netherlands Antilles	1,006	2,287	915	109	36
Subtotal	***104,848***	***240,741***	***99,888***	***12,416***	***4,497***
Sub-region IV					
Anguilla	49	112	45	5	2
Antigua and Barbuda	263	598	239	28	9
Barbados	1,050	2,394	968	117	40
British Virgin Is	94	213	85	10	3
Dominica	264	600	240	29	9
Grenada	346	788	317	38	13
Guadeloupe	1,505	3,420	1,368	164	54
Martinique	1,755	3,989	1,595	191	64
Montserrat	315	717	289	35	12
St. Lucia	671	1,526	610	73	24
St Kitts & Nevis	154	350	140	17	5
US Virgin Islands	875	1,989	795	95	32
Trin & Tob	4,117	9,416	3,851	472	166
S.V. & Grenadines	458	1,042	418	50	17
Subtotal	***11,916***	***27,154***	***10,960***	***1,324***	***450***
Sub-region V					
Bahamas	1,154	2,632	1,066	129	44
Cayman Islands	34	78	31	3	1
Cuba	73,313	167,504	68,295	8,350	2,913
Dom.Republic	22,504	52,044	22,134	2,814	1,069
Haiti	28,285	64,285	25,714	3,085	1,028
Puerto Rico	8,600	21,500	11,467	1,720	860
Jamaica	12,413	28,212	11,284	1,354	451
Turks & Caicos Is	68	156	62	7	2
Subtotal	***146,375***	***336,413***	***140,055***	***17,465***	***6,370***
Total	**277,628**	**637,335**	**264,256**	**32,824**	**11,869**

Annex 3. Industrial pollutant loads (tonnes.yr^{-1}) discharged by country and sub-region in WCR (1997 -2008)

(UNEP-RCU/CEP 2010)

Country/territory	BOD_5	COD	TSS	TN	TP
Sub-region II					
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
Subtotal	***9, 954***	***21,807***	***5,983***	***659***	***263***
Sub-region III					
Colombia	4, 000	6, 000	80, 000	1, 000	100
Venezuela	28, 559	59, 974	6 ,155	9, 605	475
Netherlands Antilles	1, 489	3, 127	438	145	88
Subtotal	***34,048***	***69,101***	***86,593***	***10,750***	***663***
Sub-region IV					
Anguilla					
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		
St. Lucia	190	399	895	38	34
St. Kitts & 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. & the Grenadines	335	704	225	9	4
Subtotal	***197,062***	***353, 883***	***42,382***	***1,326***	***631***
Sub-region V					
Cuba	44, 340	93, 083		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
Subtotal	***52, 117***	***109, 328***	***8,525***	***1, 915***	***1,287***
Total	**292,511**	**553,317**	**143,456**	**14,562**	**2,539**

Annex 4. Average pollutant load in WCR (tonnes.year^{-1}) from river basin by sub-region in WCR (2000-2008)

(UNEP-RCU/CEP 2010)

Watersheds	Drainage area (km^2)	Flow ($m^3.sec^{-1}$)	BOD_5	COD	TSS	TN	TP
			Sub-region II				
Minor basins	291, 439	2, 783	403	1, 796	5, 800	12.7	4.3
Subtotal	***291, 439***	***2, 783***	***403***	***1, 796***	***5, 800***	***12.7***	***4.3***
			Sub-region III				
Orinoco River	952, 173	32 ,321	NA	NA	105, 850	480[1]	NA
Magdalena River / Dique canal	256, 622	7 ,576	2, 983	13, 290	96, 000	95	67
Minor basins	69, 948	5 ,209	238	1, 060	433	45	53
Subtotal	***1, 278, 743***	***45, 106***	***3, 221***	***14, 350***	***202, 283***	***620***	***120***
			Sub-region IV				
Minor basins	105, 242	1, 005	1.7	8	2.6	0.2	0.04
Subtotal	***105, 242***	***1, 005***	***1.7***	***8***	***2.6***	***0.2***	***0.04***
			Sub-region V				
Minor basins	378, 871	3, 618	524	2, 335	7, 540	16.5	5.6
Subtotal	***378, 871***	***3, 618***	***524***	***2, 335***	***7, 540***	***16.5***	***5.6***
Total			**4, 000**[2]	**18 ,000**[2]	**215,438**	**656**	**148**[3]

NA: Not available

[1]Ramirez et al (1988); Lewis & Saunders (1986); Meybeck (1982).

[2]Does not include organic runoffs from sub-region I and the Orinoco River basin due to the lack of information.

[3]Does not include phosphorus runoff from the Orinoco River basin due to the lack of information.

Annex 5. List of CCA statements developed by the TTT

Annex 6. Landings and discards (tonnes) by countries

(Kelleher 2005)

Country	Landings	Discards	Discard rate %
Anguilla	225	0	0.0
Antigua and Barbuda	1,369	0	0.0
Aruba	168	0	0.0
Bahamas	10,253	0	0.0
Barbados	3,316	0	0.0
Belize	111	284	71.9
British Virgin Islands	236	0	0.0
Cayman Islands	123	0	0.0
Colombia	9,095	14,377	61.3
Costa Rica	2,683	2,437	47.6
Cuba	19,227	0	0.0
Dominica	1,104	0	0.0
Dominican Republic	942	3,964	80.8
Grenada	1,661	0	0.0
Guadeloupe	9,641	0	0.0
Guatemala	16,100	50,950	76.0
Guyana	26,870	29,960	52.7
Haiti	398	1,402	77.9
Honduras	11,815	27,335	69.8
Martinique	5,352	0	0.0
Mexico	541,423	137,873	20.3
Montserrat	46	0	0.0
Nicaragua	5,776	6,346	52.4
Panama	101,964	33,483	24.7
Saint Kitts and Nevis	295	0	0.0
Saint Lucia	1,621	0	0.0
Trinidad and Tobago	6,639	8,859	57.2
Venezuela	213,025	96,820	31.2

Annex 7. Annual non-fuel fisheries subsidy estimates by categories (US$ '000) for CLME countries

(Sumaila and Pauly 2006)

	Type of subsidy & amount (US$'000)			
Country	**[1]Good**	**[2]Bad**	**[3]Ugly**	**Total**
Ant. & Barb	357	10,419	0	10,776
Bahamas	4,771	18,649	0	23,420
Barbados	516	13,724	509	14,749
Belize	3,184	8,343	21	11,548
Colombia	6,811	4,607	6,720	18,138
Costa Rica	3,234	12,757	876	16,867
Cuba	4,057	22,238	0	26,295
Domincan Rep	3,335	5,757	0	9,092
Dominica	151	595	149	894
Grenada	221	6,180	0	6,401
Guatemala	2,068	12,649	3,818	18,535
Haiti	716	284	0	1,000
Honduras	3,022	12,158	2,981	18,161
Jamaica	366	1,124	775	2,265
Nicaragua	2,467	6,635	0	9,102
Panama	5,564	47,145	11,791	64,500
St. Kitts & Nevis	39	271	0	310
St. Lucia	219	863	216	1,297
St. Vinc & Gren	946	3,805	933	5,684
Trin & Tob	515	5,194	0	5,708
Venezuela	6,894	58,413	14,610	79,918
Total	**49,453**	**251,810**	**43,399**	**344,660**

[1]'Good subsidies' are programs that lead to investment in natural capital assets to a social optimum, which is defined as the maximum allocation of natural resources to society as a whole, i.e., by maximizing economic rent ; [2]'Bad subsidies' are defined as subsidy programs that lead to disinvestments in natural capital assets once the fishing capacity develops to a point where resource exploitation exceeds the Maximum Economic Yield; [3]'Ugly subsidies' are defined as programs that have the potential to lead to either investment or disinvestment in the fishery resource.

Annex 8. Fertilizer use (tonnes.yr^{-1} x 10^3) by countries and sub-regions in WCR in 2005

(IFDC/IFA/FAO 1997)

Subregion II		Subregion III		Subregion IV		Subregion V	
Country	***Fertilizer use***	***Country***	***Fertilizer use***	***Country***	***Fertilizer use***	***Country***	***Fertilizer use***
Belize	5.7	Colombia	466.9	Anguilla	NA	Bahamas	0.3
Guatemala	198.5	Venezuela	438.7	Antigua & Barbuda	NA	Cayman Is	NA
Honduras	102.4			Barbados	NA	Cuba	69.8
Nicaragua	56.2			British V. Is	NA	Dom. Republic	79.8
Costa Rica	232.8			Dominica	3.0	Haiti	14.4
Panama	18.8			Granada	NA	Puerto Rico	NA
				Guadalupe	NA	Jamaica	14.1
				Martinique	NA	Turks & Caicos	NA
				Montserrat	NA		
				St. Lucia	1.1		
				St. Martin	NA		
				St. Bartholomi	NA		
				San Kitts & Nevis	0.3		
				US Virgin Islands	NA		
				Trinidad & Tobago	5.7		
				S.V. & Grenadines	1.2		

Annex 9. Status of the Cartagena Convention and Protocols

(Downloaded 07 April 2011:
http://www.cep.unep.org)

state	cartagena convention		oil spill		spaw		lbs	
	date of signature	ratified / acceded	date of signature	ratified / acceded	date of signature	ratified / acceded	date of signature	ratified / acceded
Antigua and Barbuda		11-Sep-86		11-Sep-86	18-Jan-90			
Bahamas								
Barbados	05-Mar-84	28-May-85	05-Mar-84	28-May-85		14-Oct-02		
Belize		22-Sep-99		22-Sep-99		4-Jan-08		4-Jan-08
Colombia	24-Mar-83	03-Mar-88	24-Mar-83	03-Mar-88	18-Jan-90	05-Jan-98	02-Oct-00	
Costa Rica		01-Aug-91		01-Aug-91			06-Oct-99	
Cuba		15-Sep-88		15-Sep-88	18-Jan-90	04-Aug-98		
Dominica		05-Oct-90		05-Oct-90				
Dominican Republic		24-Nov-98		24-Nov-98		24-Nov-98	03-Aug-00	
France	24-Mar-83	13-Nov-85	24-Mar-83	13-Nov-85	18-Jan-90	05-Apr-02	06-Oct-99	4-May-07
Grenada	24-Mar-83	17-Aug-87	24-Mar-83	17-Aug-87				
Guatemala	05-Jul-83	18-Dec-89	05-Jul-83	18-Dec-89	18-Jan-90			
Guyana								
Haiti								
Honduras	24-Mar-83		24-Mar-83					
Jamaica	24-Mar-83	01-Apr-87	24-Mar-83	01-Apr-87	18-Jan-90			
Mexico	24-Mar-83	11-Apr-85	24-Mar-83	11-Apr-85	18-Jan-90			
Netherlands	24-Mar-83	16-Apr-84	24-Mar-83	16-Apr-84	18-Jan-90	02-Mar-92	06-Oct-99	
Nicaragua	24-Mar-83		24-Mar-83					
Panama	24-Mar-83	07-Nov-87	24-Mar-83	07-Nov-87	16-Jan-91	27-Sep-96		09-Jul-03
St. Kitts and Nevis		15-Jun-99		15-Jun-99				
Saint Lucia	24-Mar-83	30-Nov-84	24-Mar-83	30-Nov-84	18-Jan-90	25-Apr-00		30-Jan-08
St. Vincent and the Grenadines		11-Jul-90		11-Jul-90		26-Jul-91		
Suriname								
Trinidad and Tobago		24-Jan-86		24-Jan-86	18-Jan-90	10-Aug-99		28-Mar-03
United Kingdom	24-Mar-83	28-Feb-86	24-Mar-83	28-Feb-86	18-Jan-90			
United States of America	24-Mar-83	31-Oct-84	24-Mar-83	31-Oct-84	18-Jan-90	16-Apr-03	06-Oct-99	13-Feb-09
Venezuela	24-Mar-83	18-Dec-86	24-Mar-83	18-Dec-86	18-Jan-90	28-Jan-97		
European Economic Commission	24-Mar-83							