ISSN: 1995 - 1132

CRFM Technical & Advisory Document Series

Number 2013 / 8
Volume 1

CLIMATE CHANGE ADAPTATION AND DISASTER RISK MANAGEMENT IN FISHERIES AND AQUACULTURE IN THE CARIBBEAN REGION

Volume 1 — Assessment Report

CRFM Secretariat
Belize

CRFM Technical & Advisory Document - Number 2013 / 8

CLIMATE CHANGE ADAPTATION AND DISASTER RISK MANAGEMENT IN FISHERIES AND AQUACULTURE IN THE CARIBBEAN REGION:

Volume 1 - Assessment Report

Prepared by:

Patrick McConney, John Charlery and Maria Pena, CERMES, University of the West Indies, Barbados, under contract to the Caribbean Regional Fisheries Mechanism (CRFM) Secretariat.

This publication has been made possible through funding provided by the United Nations Food and Agriculture Organisation (FAO).

www.crfm.int

www.youtube.com/TheCRFM

www.facebook.com/CarFisheries

www.twitter.com/CaribFisheries

CRFM Secretariat
Belize 2013

CRFM Technical & Advisory Document - Number 2013 / 8

CLIMATE CHANGE ADAPTATION AND DISASTER RISK MANAGEMENT IN FISHERIES AND AQUACULTURE IN THE CARIBBEAN REGION:

Volume 1 - Assessment Report

Correct Citation:
CRFM, 2013. McConney, P., J. Charlery, M. Pena. Climate Change Adaptation and Disaster Risk Management in Fisheries and Aquaculture in the Caribbean Region. Volume 1 – Assessment Report. *CRFM Technical & Advisory Document*, No. 2013 / 8. 93 p.

ISSN: 1995-1132
ISBN: 978-976-8165-78-7

Published by the Caribbean Regional Fisheries Mechanism Secretariat
Belize and St. Vincent and the Grenadines

SUMMARY

This assessment is the first of four outputs in this initiative of CRFM and FAO on ‘Climate change adaptation and disaster risk management in fisheries and aquaculture in the CARICOM region’.

Using available information the assessment is intended to:

- assess vulnerability to disasters and climate change in CARICOM countries by understanding potential impacts to the system, the sensitivity of the system to such changes and the current adaptive capacity of the system
- identify gaps in the existing knowledge to assess vulnerability in this system
- identify potential measures for reducing vulnerability to disasters and climate change
- provide policy guidance to reduce the system’s vulnerability within the wider sustainable development objectives

Fisheries and aquaculture in the CARICOM region are extremely vulnerable to the impacts of climate change and variability, and to several hazards that typically result in disasters. The concern is with hydro-meteorological and geological hazards while acknowledging interaction with technological hazards as well. Agencies in the region see considerable convergence between CCA and DRM and encourage an integrated approach. Of prime concern to many stakeholders are the negative impacts of storms and hurricanes on small-scale marine fisheries. Despite the regional downscaling of global climate models there remains considerable uncertainty about the physical and chemical changes, variability and hazards that may arise, especially as they interact with each other, and the biological responses of flora and fauna, including humans. The region needs to be prepared for bad surprises.

Numerous completed, ongoing and planned activities tackle increasing adaptive capacity and reducing vulnerability, but few focus specifically on fisheries and aquaculture. A concerted and comprehensive approach to mainstreaming CCA and DRM into fisheries and aquaculture is urgently required. Such an approach will need to focus on institutional arrangements for building the capacity to deliver and absorb initiatives as well as the more technical aspects of interventions if they are to be sustainable.

Several measures for accomplishing this are recommended. These measures should be integrated into existing regional frameworks related to climate, disasters, fisheries and aquaculture in order to take advantage of political will and endorsement, and to leverage resources committed to these areas. This strategy and action plan and the development of a programme proposal for implementation are contained in two other reports in this series.

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

ACCC	Adaptation to Climate Change in the Caribbean Project
ACS	Association of Caribbean States
AMMP	Anguilla Marine Monitoring Programme
AOSIS	Alliance of Small Island States
AR4	Fourth Assessment Report (IPCC)
ASSC/TMAC	Agriculture Sub-Sector Committee/Technical Management Advisory Committee
CANARI	Caribbean Natural Resources Institute
CARDIN	Caribbean Disaster Information Network
CAREC	Caribbean Epidemiological Centre
CARICOM	Caribbean Community
CAS	Complex adaptive system
CBD	Convention on Biological Diversity
CBO	Community-Based Organization
CCA	Climate Change Adaptation
CCA2DRR	Mainstreaming Climate Change Adaptation into Disaster Risk Reduction
CCCFP	Caribbean Community Common Fisheries Policy
CCCCC	Caribbean Community Climate Change Centre
CCCRA	CARIBSAVE Climate Change Risk Atlas
CCDM	Mainstreaming Climate Change into Disaster Risk Management
CCRF	Code of Conduct for Responsible Fisheries
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CDB	Caribbean Development Bank
CDEMA	Caribbean Disaster and Emergency Management Agency
CDERA	Caribbean Disaster and Emergency Response Agency
CDKN	Climate and Development Knowledge Network
CDM	Comprehensive Disaster Management
CDPMN	Caribbean Drought and Precipitation Monitoring Network
CDRU	CARICOM Disaster Response Unit
CEHI	Caribbean Environmental Health Institute
CERMES	Centre for Resource Management and Environmental Studies
CGCED	Caribbean Group for Cooperation in Economic Development
CIDA	Canadian International Development Agency
CIF	Climate Investment Fund
CIMH	Caribbean Institute for Meteorology and Hydrology
CLME	Caribbean Large Marine Ecosystem (Project)
COFCOR	Council for Foreign and Community Relations
COP	Conference of the Parties to a MEA
COTED	Council for Trade and Economic Development
CPACC	Caribbean Planning for Adaptation to Climate Change
CREDP	Caribbean Renewable Energy Project
CREWS	Coral Reef Early Warning System
CRFM	Caribbean Regional Fisheries Mechanism
CRIS	Coastal Resource Information System
CRMI	Caribbean Risk Management Initiative
CRMN	Caribbean Reef Monitoring Network
CROSQ	CARICOM Regional Organization for Standards and Quality
CSCDM	Climate Smart Community Disaster Management
CSG	Climate Studies Group of the UWI
CSME	Caribbean Single Market and Economy
CVCA	Climate Vulnerability and Capacity Analysis
CWWA	Caribbean Water and Wastewater Association

CXC	Caribbean Examination Council
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DDS	Dynamic Downscaling
EAA	Ecosystem approach to aquaculture
EAF	Ecosystem approach to fisheries
EBM	Ecosystem based management
ECACC	Enhancing Capacity for Adaptation to Climate Change
ECDG	Eastern Caribbean Donor Group for Disaster Management
ECLAC	Economic Commission for Latin America and the Caribbean
EIA	Environmental Impact Assessment
ENSO	El Niño Southern Oscillation
ESDU	Environment and Sustainable Development Unit of the OECS
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GCCA	Global Climate Change Alliance
GCM	Global Circulation Model
GEF	Global Environment Facility
GFDRR	Global Facility for Disaster Reduction and Recovery
GGCA	Global Gender and Climate Alliance
GHG	Greenhouse Gas
GIS	Geographic Information System
HAB	Harmful Algal Blooms
HFA	Hyogo Framework for Action
IBRD	International Bank for Reconstruction and Development
ICM	integrated coastal management
IDB	Inter-American Development Bank
IDRC	International Development Research Centre
IFAD	International Fund for Agricultural Development
IFIs	International Financial Institutions
IFRCS	International Federation of Red Cross Societies
IICA	Inter-American Institute for Cooperation on Agriculture
INSMET	Institute of Meteorology (Cuba)
IOC	Intergovernmental Oceanographic Commission
IOCARIBE	Caribbean section of the International Oceans Commission
IP	Implementation Plan
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
ITCZ	Inter-tropical Convergence Zone
IUCN	International Union for the Conservation of Nature
JICA	Japan International Cooperation Agency
LAC	Latin America & the Caribbean
M&E	Monitoring and Evaluation
MACC	Mainstreaming Adaptation to Climate Change
MARPOL	International Convention for the Prevention of Pollution from Ships
MDG	Millennium Development Goal
MEA	Multilateral Environmental Agreement
MPA	Marine Protected Area
MSD	Mid-summer drought
NAPA	National Adaptation Programme of Action
NBSAP	National Biodiversity Strategy and Action Plan
NCCA	National Climate Change Adaptation
NCCC	National Climate Change Committee
NCSA	National Capacity for Self Assessment
NDO	National Disaster Office

NEMO	National Emergency and Management Office
NEMS	National Environmental Management Strategy
NEPA	National Environmental Protection Agency, Jamaica
NFP	National Focal Points
NGO	Non-governmental Organisation
NISP	National Integral Strategic Plan
NOAA	National Oceanic and Atmospheric Association
NRM	Natural Resource Management
OAS	Organization of American States
ODPEM	Office of Disaster Preparedness and Emergency Management, Jamaica
OECD	Organization for Economic Cooperation and Development
OECS	Organization of Eastern Caribbean States
OTEC	Ocean Thermal Energy Conversion
PAHO	Pan American Health Organization
PIOJ	Planning Institute of Jamaica
PPCR	Pilot Program for Climate Resilience
PRECIS	Providing Regional Climates for Impacts Studies
RCM	Regional Circulation Model
REDD	Reducing Emissions from Deforestation and Forest Degradation
SES	social-ecological system
SGP	Small Grants Programme
SIDS	Small Island Developing States
SLM	Sustainable Land Management
SLR	Sea Level Rise
SMMA	Soufrière Marine Management Area
SPACC	Special Program on Adaptation to Climate Change
SPAW	Specially Protected Areas and Wildlife
SPCR	Strategic Program for Climate Resilience
SRES	Special Report on Emission Scenarios
SST	Sea Surface Temperature
TNC	The Nature Conservancy
TOR	Terms of Reference
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Education Fund
UNITAR	United Nations Institute for Training and Research
UNWTO	United Nations World Tourism Organization
US	United States
USAID	United States Agency for International Development
USD	United States Dollar
UWI	University of the West Indies
VCA	Vulnerability and Capacity Assessment
WB	World Bank
WECAFC	Western Central Atlantic Fishery Commission
WHO	World Health Organization
WMO	World Meteorological Organization
WRI	World Resources Institute
WWF	World Wildlife Fund

1 INTRODUCTION

The interests of the key agencies provide the immediate context, scope and purpose of this work. The topic ‘Climate change adaptation and disaster risk management in fisheries and aquaculture in the CARICOM region’ is immense. This section explains the scope of the topic, describes the approach to implementing this work, and sets out its communication and organisation into a package.

1.1 Context and purpose

The Caribbean Regional Fisheries Mechanism (CRFM)[1] was established by the Caribbean Community (CARICOM)[2] in February 2002. Its mission is to promote and facilitate the responsible utilization of the Region’s fisheries and other aquatic resources for the economic and social benefits of the current and future population of the region. The CRFM notes that fisheries and aquaculture are important to Caribbean people, contributing to livelihoods, nutrition, food security, economies, culture and many other dimensions of human well-being. Yet, their contributions are threatened by vulnerabilities of the individual people and multi-component institutions of these aquatic sectors, both to disasters and climate change/variability. There are gaps between what occurs now and what is needed to best address these deficiencies. These gaps need urgently to be closed given that relatively little work has been done on fisheries and aquaculture compared, for example, to the agriculture or tourism sectors.

Within the Caribbean region, closing the gaps in order to achieve sustainability of fisheries resources and aquaculture is of critical concern to the CRFM, the objectives of which are:

(a) the efficient management and sustainable development of marine and other aquatic resources within the jurisdiction of Member States;

(b) the promotion and establishment of cooperative arrangements among interested States for the efficient management of shared, straddling or highly migratory marine and other aquatic resources; and

(c) the provision of technical advisory and consultative services to fisheries divisions of Member States in the development, management and conservation of their marine and other aquatic resources.

CRFM asserts that if we are to ensure that the benefits which flow from fisheries and aquaculture to communities and nations in the CARICOM sub-region are to continue, then it is essential that sound strategies and action plans are developed to build resilience to disasters and climate change. The many types of connections between hazards and climate change adaptation (CCA), especially in these small island developing states (SIDS), suggest the need for proactive and integrated approaches to address them simultaneously and comprehensively. For example, linkages between disaster preparedness, response and rehabilitation suggest the need for disaster risk management (DRM) and not just risk reduction (DRR). Greater emphasis on ecosystem-based and precautionary approaches to fisheries and aquaculture is likewise essential. According to the CRFM, these need to be more closely linked to wider sustainable development processes and fully mainstreamed into both sectoral and cross-sectoral policies, plans, programmes and projects. Effective DRM linked to CCA requires high degrees of coordination and cooperation between agencies at global, regional, sub-regional, national and local levels. These tie into multi-level governance of aquatic resources.

[1] http://www.caricom-fisheries.com/

[2] http://www.caricom.org/

The Caribbean Community Climate Change Centre (CCCCC)[3], since its establishment in 2005, has coordinated the CARICOM response to climate change. The Centre is a key node for information on climate change issues and adaptation in the Caribbean. It is a regional repository and clearing house for climate data, providing climate-related policy advice and guidelines to CARICOM Member States. In this capacity, it spearheaded formulation of the 'Regional Framework for Achieving Development Resilient to Climate Change' (the Regional Framework) [4] which articulates CARICOM's strategy on climate change. CARICOM Heads of Government endorsed the Regional Framework at their July 2009 meeting in Guyana and issued the Liliendaal Declaration which sets out key climate change related interests and aims of CARICOM Member States. The Implementation Plan (IP) for the Regional Framework is entitled "Delivering transformational change 2011 - 2021"[5]. CRFM fisheries and aquaculture initiatives should be integrated into the IP following the CCCCC approach to unifying coordination, planning, monitoring and evaluation. Thus the IP plays a central role in this study.

A high priority CRFM strategic programme area is "Development and promotion of risk reduction programmes for fishers". The Caribbean Disaster Emergency Management Agency (CDEMA)[6], established in 1991 as the Caribbean Disaster Emergency Response Agency (CDERA), is the leading disaster risk management organization within CARICOM with linkages to a wide array of other support and response agencies. CDEMA, functions under an expanded mandate of Comprehensive Disaster Management (CDM) and is designed to embrace the principles and practices of CDM which seeks to reduce the risk and loss associated with natural and technological hazards, and the impacts of climate change and variability, to enhance sustainable development regionally. A guiding document for DRM is the Enhanced CDM Framework for 2007-2012[7]. CDEMA is another key partner in this study.

The FAO Western Central Atlantic Fishery Commission (WECAFC)[8] has been active since 1974. The Commission's objective is to promote the effective conservation, management and development of the living marine resources of the area of competence of the Commission, in accordance with the FAO Code of Conduct for Responsible Fisheries (CCRF)[9], and address common problems of fisheries management and development faced by members of the Commission. The Caribbean Community Common Fisheries Policy (CCCFP)[10] which was endorsed by the CRFM Ministerial Council in May 2011and the draft fisheries management plans of several Member States are guided by the Code which highlights stakeholder participation and partnerships among agencies as being crucial for its implementation. Disaster Risk Management in Fisheries, which included climate change and variability, was on the agenda of the 14th Session of WECAFC, held in Panama, in February 2012, indicating the importance of the subject in the Wider Caribbean Region. FAO (Rome) and WECAFC are also partners in this initiative and FAO is the main financial supporter of the study.

[3] http://www.caribbeanclimate.bz/
[4] CCCCC. 2009. Climate Change and the Caribbean: A Regional Framework for Achieving Development Resilient to Climate Change (2009 - 2015). Caribbean Community Climate Change Centre, Belmopan, Belize
[5] CCCCC. 2012. Delivering transformational change 2011 - 2021: Implementing the CARICOM `Regional Framework for Achieving Development Resilient to Climate Change. Caribbean Community Climate Change Centre, Belmopan, Belize
[6] http://www.cdema.org/
[7] CDERA. 2007. CDM Strategy and Programme Framework 2007-2012. Caribbean Disaster Emergency Response Agency, Barbados.
[8] http://www.fao.org/fishery/rfb/wecafc/en
[9] http://www.fao.org/fishery/code/en
[10] CARICOM. 2010. Agreement Establishing the Caribbean Community Common Fisheries Policy. Caribbean Community.

The mandates of the above key agencies provide the immediate context for this initiative, the purpose of which is: "to strengthen regional and national cooperation and develop capacity in addressing climate change impacts and disasters in the fisheries and aquaculture sector". In order to achieve this an assessment study report, strategy action plan, and results-based programme proposal on disaster risk management, climate change adaptation in fisheries and aquaculture in the CARICOM region were prepared by CERMES. A regional workshop on "Formulation of a strategy, action plan and programme proposal on disaster risk management and climate change adaptation in fisheries and aquaculture in the CARICOM region" was organised involving CERMES, CRFM, CDEMA, CCCCC, FAO / WECAFC and other members of the multi-agency Agriculture Sub-Sector Committee / Technical Management Advisory Committee (ASSC/TMAC). The workshop followed one on the International Guidelines for Securing Sustainable Small-Scale Fisheries (SSF Guidelines)[11] in order to further strengthen linkages among common interests.

1.2 Scope and implementation

The core geographic scope of this consultancy comprises the 17 members of the CRFM which are 15 full CARICOM Member States (Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, Saint Lucia, St. Kitts and Nevis, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago) plus two Associate Members, Anguilla and Turks and Caicos Islands. Outside this core the study occasionally also considers connections to other Caribbean countries such as Cuba, Puerto Rico and the Dominican Republic to other SIDS regions such as the Pacific and to the many international initiatives and agencies that address the global issues of climate and disasters. Within the CRFM or CARICOM, the Organisation of Eastern Caribbean States (OECS)[12] is an extremely critical sub-region containing the majority of members in a fairly compact area.

The policy instruments that address CCA and DRM issues range from multilateral environmental agreements (MEAs) to national strategies. Some attention is paid to global instruments and initiatives related to climate and disaster, but more emphasis will be placed on regional and national policies such as the Regional Framework and IP mentioned previously. Trends such as towards low carbon green (and blue) economies and the themes emerging from major global events such as Rio+20 will also receive less attention than more regional and specifically SIDS perspectives, but will not be ignored.

The Implementation Plan for transformational change and the recent Inter-Governmental Panel on Climate Change special report on 'Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation'[13] make abundant use of concepts associated with complex adaptive social-ecological systems, and this study does as well. These concepts are particularly useful for tackling ecosystem based management (EBM), the ecosystem approach to fisheries (EAF) and aquaculture (EAA) and other such integrative schemes of humans-in-nature. Complex adaptive system (CAS) and social-ecological system (SES) perspectives are also consistent with the emerging

[11] http://www.fao.org/fishery/ssf/guidelines/en
[12] http://www.oecs.org/
[13] IPCC. 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.

regional governance framework for marine resources in the Wider Caribbean Region as evidenced by the Caribbean Large Marine Ecosystem (CLME) project[14] to which the IP often refers.

Fisheries and aquaculture are the central economic activities to be addressed primarily from the livelihoods perspective[15] favoured by FAO and other agencies. Accordingly the scope for this study is mainly small-scale and commercial, but some attention is paid to larger scales of operation (e.g. in aquaculture) and recreation (e.g. in fisheries). The focus is also more on marine than freshwater aquatic systems since the former contain the bulk of the economic activity in the region. We examine the full length of the value chain and take an inter- or cross-sectoral perspective consistent with an ecosystem approach. Since the latter can be broad we focus on some critical interactions such as with tourism and agriculture, and through integrated coastal management (ICM). The study concerns both CCA and DRM in fisheries and aquaculture. These topics overlap considerably but not completely. More attention will be paid to the specific areas of greatest overlap as explained later in greater detail.

Ecosystem approaches often entail the involvement of a great diversity of stakeholders. We narrow our concern to the primary stakeholders (direct users and management authorities) and secondary stakeholders (indirect dependents and highly influential other parties). Much attention is paid to governmental and inter-governmental agencies, but non-governmental and community based organisations (NGOs and CBOs) are not ignored. They play different roles in the institutions of multi-level governance.

Development of the study is in consultation with the key partner agencies identified earlier, and especially CRFM. A wider set of stakeholders is reached via internet and other communication. The country visits are an important part of the implementation strategy. Their purpose is partly to help validate information in draft outputs, but mainly to get feedback on the way forward with getting strategies and proposals for action from paper into practice. This was the focus of the workshop.

1.3 About the outputs

Each of the objectives of the consultancy has expected outputs associated with it. These are:

Objective	Expected output
Using available information, the case study will • assess vulnerability to disasters and climate change in CARICOM countries by understanding potential impacts to the system, the sensitivity of the system to such changes and the current adaptive capacity of the system; • identify gaps in the existing knowledge to assess vulnerability in this system, • identify potential measures for reducing vulnerability to disasters and climate change; • provide policy guidance to reduce the system's vulnerability within the wider sustainable development objectives;	**Assessment study** on the interface between DRM, CCA and fisheries and aquaculture in the CARICOM region, with a focus on small scale fisheries and small-scale aquaculture
• develop strategy and action plan for integrating DRM, CCA and fisheries and	**Strategy and action plan** for integrating DRM, CCA and fisheries and aquaculture, with a focus

[14] http://www.clmeproject.org/

[15] Badjeck, C., E. H. Allison, A. S. Halls and N. Dulvy. 2010. Impacts of climate variability and change on fishery-based livelihoods. Marine Policy 34: 375 – 383

Objective	Expected output
aquaculture, with a focus on small-scale fisheries (SSF) and small-scale aquaculture (SSA);	on small-scale fisheries (SSF) and small-scale aquaculture (SSA)
• develop a program for funding;	**Results-based programme proposal** with supporting project concept notes towards implementation and resource mobilization
• workshop report	**Workshop report**

These outputs are intended for different audiences including inter-governmental and governmental agencies, universities, private sector bodies, NGOs and CBOs. Readers are likely to be policy advisers, scientific or technical officers, senior administrators, academics, civil society organisers, and fishing industry leaders. Policy-makers (e.g. ministers), the general public and students are some important categories for communication on CCA and DRM that are not targeted by this study. The study also has defined communication pathways and products. The main pathway is the face-to-face regional workshop, with internet access playing a minor role. The main products are paper and electronic reports, extracts from which can yield web page content, slides and policy briefs.

In order to meet the needs of the diverse audiences, and the limited pathways and products, the outputs must be communicated by text and graphics that are as simple and easy to understand as the topic allows. Although the topic is highly technical / scientific we try to:

- minimize scientific referencing and technical jargon where possible
- provide a list of acronyms and a glossary of technical explanations
- employ direct and simple language (which also facilitates translation)
- engage the reader with comments and questions to prompt reflection
- refer to web sites and other sources of easily accessible information
- avoid reproducing large sets of information available elsewhere
- use bulleted lists, tables and charts sourced from existing publications

After this introduction the next section of the assessment study sets the scene with key concepts so that readers can be clear on what is being referred to and why. Then we provide an overview of climate change, variability and disasters in the Caribbean before a more specific focus on fisheries and aquaculture impacts and issues. The final section looks at some of the measures that may be taken to reduce vulnerability and increase resilience, thereby filling the gaps in adaptive capacity.

The strategy and action plan addresses identified gaps with broad ideas on what needs to be done in association with the IP for the regional climate change framework, with CDM, with the Code, with the CARICOM Common Fisheries Policy, with national fisheries and aquaculture plans and more. The emphasis is in adding value to what already exists or is planned, and to create new synergies.

This emphasis is carried through into the results-based programme proposal with suggestions for resource mobilisation and implementation. It is expected that the regional workshop will focus much of its attention on this and the previous output in order to effectively and efficiently translate ideas into action.

The regional workshop report is the final output that ties all of the above together by synthesising the interventions and decisions of its participants, and particularly the directions that CRFM member states and partner agencies advocate be taken by various stakeholders and interested parties.

2 SETTING THE SCENE

Building upon the introduction, this section sets out in more detail several of the key concepts of the study, the principal actors involved, their interests and the linkages among all of these that constitute the fisheries and aquaculture systems investigated. We emphasise high complementarity between the approaches to addressing CCA and DRM, and increasing integration to create synergies. We look briefly at some of the main themes and trends that guide CCA and DRM in the CARICOM region.

2.1 Key concepts and their connections

This assessment study crosses and connects several conceptual frameworks and disciplines. We do not expect diverse audiences to be experts in fisheries, aquaculture, CCA and DRM. Several of the concepts and technical terms will be unfamiliar even to professionals in one or the other field. To assist communication across disciplines and professions we provide a glossary in an Annex. In it are some of the most common terms used in several fields along with fairly straightforward explanations. For each term one can find several more definitions, each often wedded to a particular discipline or field (e.g. engineering versus ecological resilience), and there are hundreds more terms in use. The main point is not to focus on technical/scientific details but to see the several broad areas of similarity and connectedness in order to build upon common ground as the basis for collaboration.

In this study, when we refer to fisheries and aquaculture our emphasis is on small-scale enterprises. This is not to entirely exclude industrial fisheries (e.g. some shrimp trawling) and aquaculture (e.g. some large shrimp farms), but to recognise that the majority of people engaged in fisheries and aquaculture are small-scale in this region, as in most parts of the world. The fisheries in the region are mainly marine capture fisheries for demersal (bottom-dwelling) and pelagic (open water) species that occur inshore (from the coast, wetlands or estuaries to several miles off) or offshore (beyond inshore to the limits of maritime jurisdiction or the high seas) (Figure 2.1).

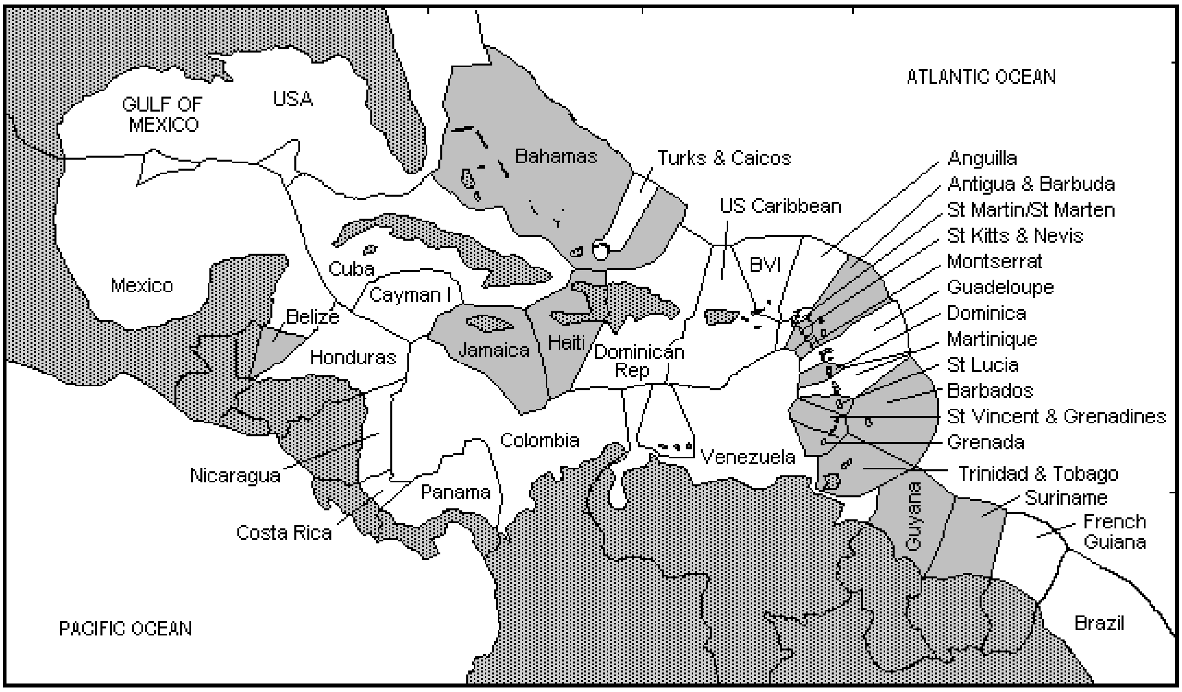


Figure 2.1 The wider Caribbean region highlighting hypothetical EEZs of CARICOM countries (Adapted from Haughton et al. 2004)

Inland freshwater (river and lake) fisheries occur in few CRFM countries. Aquaculture spans many aquatic systems, grows both plants and animals, and features several production systems some of which may be integrated with agriculture. It is currently less significant than capture fisheries in most CRFM countries, but is of importance in some such as Belize and Jamaica. New aquaculture policies, plans and projects are in progress in a few countries such as St Kitts and Nevis. The FAO paper by Cochrane and others[16] offers a comprehensive overview in relation to climate change.

The glossary explains several technical terms used in climate change and variability, but our interest is primarily in adaptation, which is also a central theme in DRM. Simply put, adaptation is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. The glossary also explains several technical terms related to disasters, but our main interest is in disaster risk management which is the systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster. DRM features a planned sequence of events (Figure 2.2).

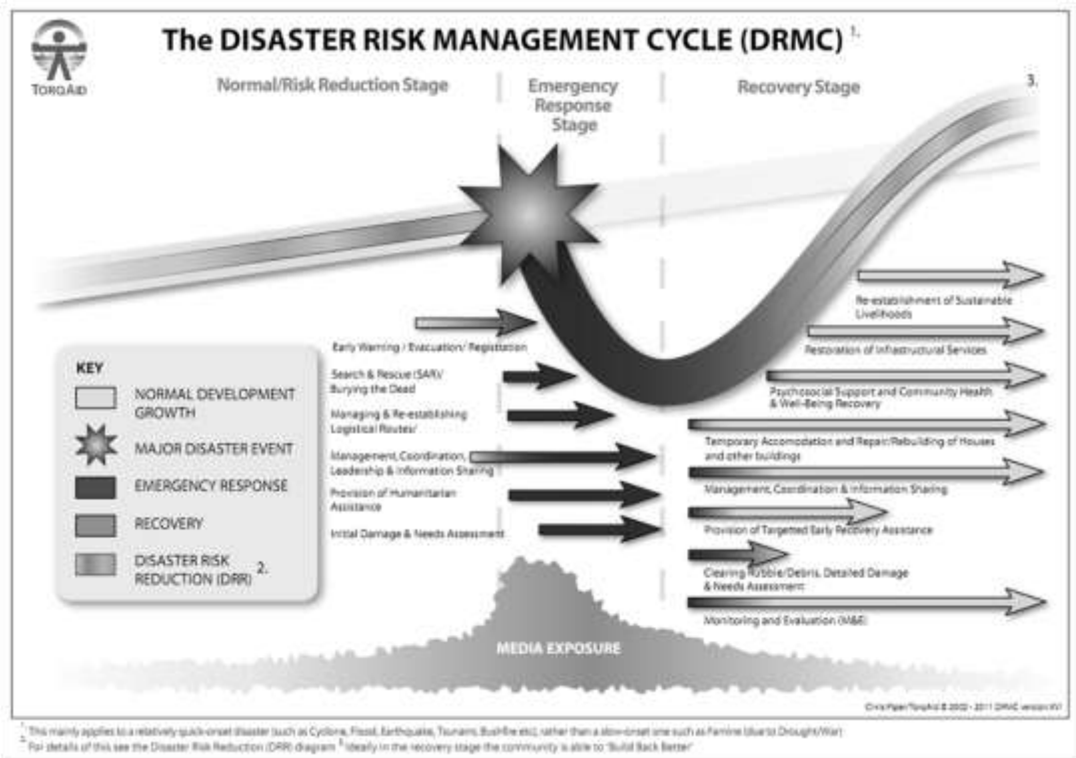


Figure 2.2 Disaster risk management cycle
(Source: TorqAid at http://www.torqaid.com/images/stories/latestDRMC.pdf)

CCA and DRM have several other areas of overlap such as among hazards, sectors impacted and possible responses (

Figure 2.3). We focus mainly on this area of hydro-meteorological overlap, not ignoring but paying less attention to hazards that are not directly related to climate such as the geological hazards of

[16] Cochrane, K.; De Young, C.; Soto, D.; Bahri, T. (eds). 2009. Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO. 212p

earthquakes and tsunamis. Due to small geographic size, small economies, close links among social and economic activities, and other features of SIDS, the potential impacts of different hazards are likely to be similar as are the dimensions of adaptive capacity required to reduce vulnerability and build resilience.

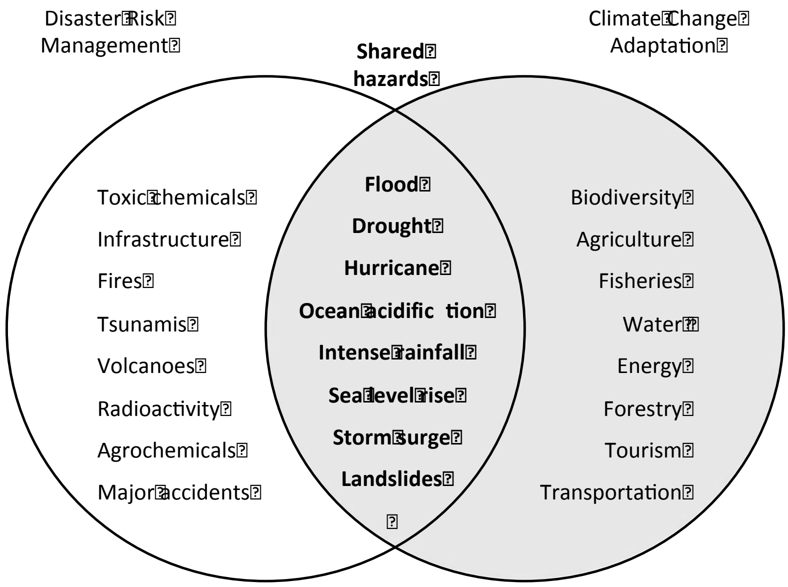


Figure 2.3 CCA and DRM have much in common (Adapted from Carby 2012)

There is increasing convergence of CCA and DRM (Figure 2.4) especially as indirect pathways are taken into account and risk-oriented adaptive management becomes more important than the source and type of risk or driver for adaptation.

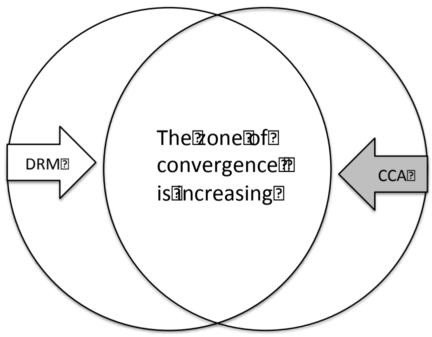


Figure 2.4 Increasing zone of CCA/DRM convergence

Another connection is that at the core of both DRM and CCA is the aim to increase capacity to adapt, and be resilient, in order to reduce vulnerability[17]. Some authors consider the increasing zone of convergence to be essential for making real progress in both spheres and explain the real and

[17] FAO. 2007. Building adaptive capacity to climate change. Policies to sustain livelihoods and fisheries. New Directions in Fisheries – A Series of Policy Briefs on Development Issues. No. 08.

perceived differences in detail in order to facilitate increased understanding[18]. Some of the technical terms for evaluating vulnerability, and their relationships, are explained in Figure 2.5.

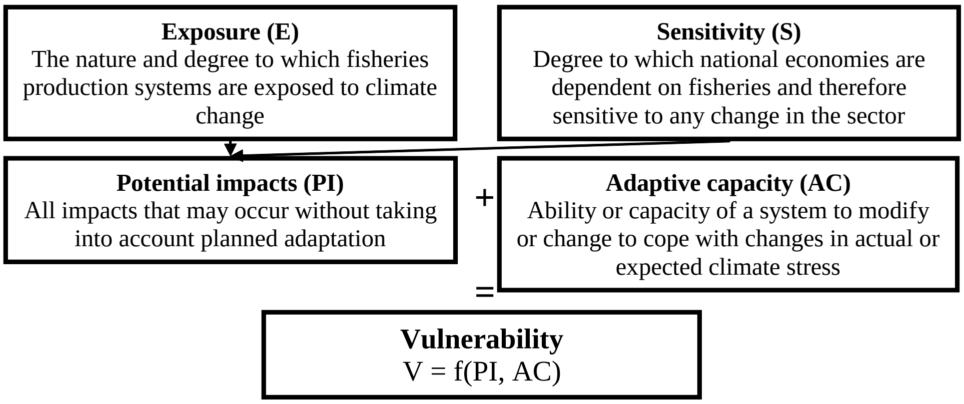


Figure 2.5 A model for evaluating vulnerability of the fisheries and aquaculture sector (Source: FAO 2007)

It is important to appreciate that adaptive capacity is multi-dimensional and that maladaptation can also occur, and increase vulnerability (pe 2.6).

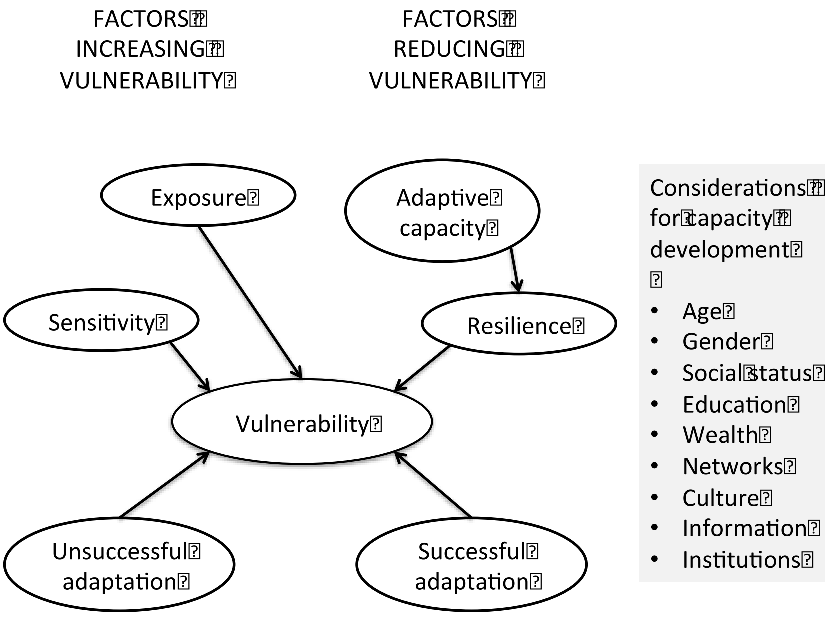


Figure 2.6 Adaptive capacity is critical for building resilience and reducing vulnerability
(Adapted from Global Climate Change Alliance)

This happens when the most appropriate programmes are not put in place or valuable assets (e.g. local knowledge, social networks, etc.) are ignored or harmed by well-intentioned but poorly planned interventions. The latter may be measures that deliver short-term gains or socio-economic benefits but, like coping strategies generally, can eventually lead to exacerbated vulnerability in the medium to

[18] Mitchell, T., M. Van Aalst and P. Silva Villanueva. 2010. Assessing Progress on Integrating Disaster Risk Reduction and Climate Change Adaptation in Development Processes, Strengthening Climate Resilience Discussion Paper 2, Institute of Development Studies, UK

long term rather than to adaptation. These perspectives on outputs and outcomes along various timescales are pertinent to project-oriented interventions. This is especially so for ensuring that outcomes are beneficial to sustainable livelihoods.

Although not all issues can be addressed from a livelihoods perspective the sustainable livelihoods framework (Figure 2.7) integrates many key concepts. We see how vulnerability provides the context for developing livelihood assets that (through policies, institutions and processes) strategically result in livelihood outcomes. Positive and negative feedback through learning helps people to adapt.

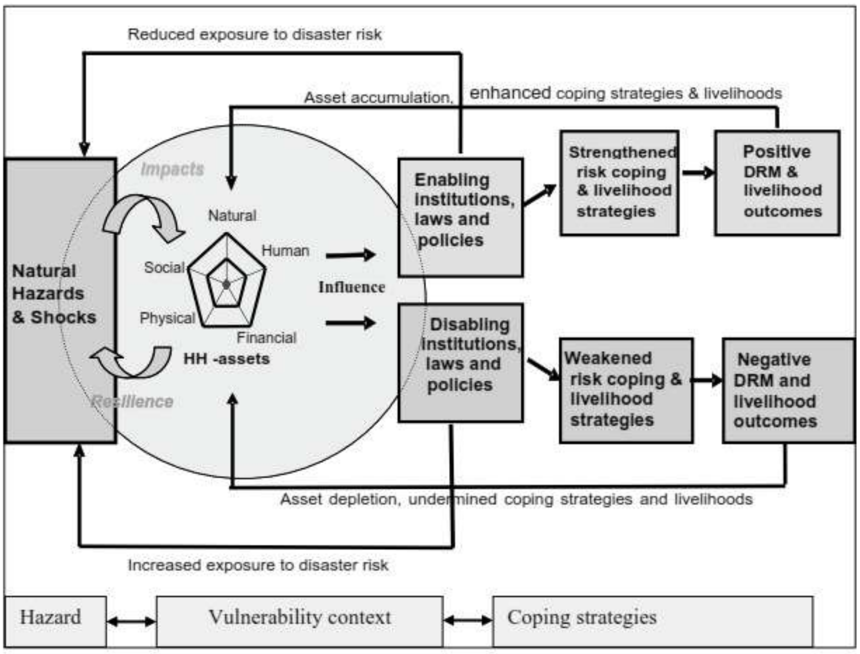


Figure 2.7 Sustainable livelihoods framework adapted to DRM (Source: Baas and others 2008)

Livelihoods are of interest from individual and household through to sector and regional levels, cutting across ecological, cultural, economic, social and political areas. Combining several of the conceptual frameworks previously described, Badjeck and others (2010) examine how livelihoods relate to climate change adaptation and can incorporate disaster risk management.

Yet another connection among the preceding key concepts is that they fit well within the emerging thrust towards ecosystem-based management (EBM) in the Wider Caribbean Region (WCR)[19] of which CARICOM is a sub-region. More specifically, we are concerned with an ecosystem approach to fisheries (EAF) which FAO describes as balancing diverse societal objectives, by taking account of the knowledge and uncertainties of biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries[20]. In this study, when we speak of fisheries we include aquaculture unless specially mentioned otherwise. Furthermore, to address adaptive capacity, we want to focus mostly on the

[19] Fanning, L., R. Mahon and P. McConney. [Eds]. 2011. Towards marine Ecosystem-Based Management in the Wider Caribbean. Amsterdam University Press, Netherlands. 428pp.
[20] FAO. 2003. The ecosystem approach to fisheries. Issues, terminology, principles, institutional foundations, implementation and outlook. FAO Fisheries Technical Paper No. 443. Rome 71pp

human dimensions of EAF[21]. Evident in all of the above, but particularly the latter, is the fact that the fisheries and aquaculture sectors are complex adaptive social-ecological systems[22]. In the next section we introduce what we mean by this in the CARICOM region.

2.2 Fisheries and aquaculture social-ecological systems in the CARICOM region

Fisheries and aquaculture social-ecological systems (SES) in the CARICOM region are quite diverse and dynamic. It would not be useful to catalogue the entire range of SES here, but in this assessment we provide examples and overviews with specific reference to CCA and DRM. In this section we lay out some of the main parameters that we take into account as we identify systems and groups of systems (e.g. as occurs in a national plan). Following on from EAF above, the systems need to be considered as complete fisheries/aquaculture value chains and cross-sectoral links must be taken into account. We consider from habitat, through harvest and postharvest to marketing, distribution and consumption to complete the value chain. We also consider linkages, for example with tourism and agriculture, along the entire length of the value chain. Indeed the image becomes one of a network rather than a chain when all of the connections are added. Some of these connections concern the governance of fisheries and aquaculture since governmental, private sector and non-governmental stakeholders need to be identified and added throughout for each SES. Considerations of CCA and DRM need to be weaved into the complexity of the fish chain (Figure 2.8)

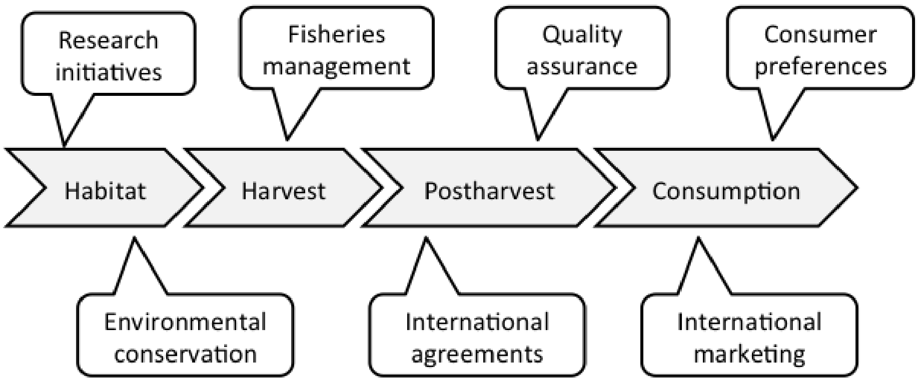


Figure 2.8 The fish chain (or net) into which CCA and DRM need to be weaved

To dissect even one fishery or aquaculture SES (the Grenada tuna fishery or Jamaica tilapia culture) in this detail for CCA and DRM is a massive undertaking. There are few papers and reports that do this comprehensively for even one fishery in one location in one country. We need to encourage more such analyses, perhaps by graduate students as well as other investigators. For our assessment of conditions and action programme related prospects in the 17 CRFM countries we must generalise. In keeping with other initiatives in the region (e.g. CLME project), except for specific examples and proposals, besides inland freshwater fisheries our marine fisheries categories will be reef (including finfish, lobster and conch), pelagic (both large and small fishes) and continental shelf (mainly shrimp and groundfish). For aquaculture we use marine (mainly intensive cage or tank culture) and freshwater (ponds or tanks of various sizes and integrated systems) as the main categories.

[21] De Young, C., A. Charles and A. Hjort. 2008. Human dimensions of the ecosystem approach to fisheries: an overview of context, concepts, tools and methods. FAO Fisheries Technical Paper. No. 489. Rome, FAO. 152p.
[22] Berkes, F. and C. Folke, eds. 1998. Linking social and ecological systems: management practices and social mechanisms for building resilience. Cambridge University Press, Cambridge, UK. 459 pp

This situation assessment provides background and context to the main aim of this initiative which is to develop an action strategy with specific programme proposals. Governance is especially important if the latter are to be implemented. Within the SES governance over fisheries, aquaculture, CCA and DRM comprises several agencies and organisations which may or may not communicate, cooperate, coordinate or collaborate (all of which are different). For example, fisheries and aquaculture are often both the responsibility of the fisheries authority, but CCA may be addressed by coastal management, physical development or environmental agencies. Similarly, DRM is normally led by a disaster management office with links to sectoral and community bodies. Recall the critical roles that these agencies play in livelihoods via transforming policies, institutions and processes. It would be useful, but beyond the scope of this study, to perform institutional analyses for each CRFM country, even if not each fishery or group of similar fisheries or SES. The general rule is that there will be a mix of state and non-state actors that change with geographic location and system conditions.

2.3 Major actors and interests

The introduction to this study identified CCCCC, CDEMA and CRFM as key regional CARICOM agencies along with FAO / WECAFC spanning regional to global levels. It also identified the Regional Framework and Implementation Plan as critical because of existing high level political endorsement, considerable participatory preparation, and their approach to integrating fisheries, aquaculture and DRR and/or DRM into the IP especially. The CRFM specifically requested that the programme proposals be framed within the IP for the two sectors, and this is consistent with FAO / WECAFC initiatives.

Chapter 8 of the IP sets out the "Role of stakeholders", having identified them in the categories of:

- Regional stakeholders
    - E.g. CARICOM Heads of Government, ministerial bodies and organisations, CDB
- National governments
    - E.g. Parliament, Cabinet, ministries, departments, statutory and cross-sectoral bodies
- Private sector
    - E.g. large corporations to small businesses, chambers of commerce, financial institutions such as banks, credit unions and insurance bodies
- NGOs, CBOs and wider civil society
    - E.g. Fisherfolk organizations, CANARI, Panos Caribbean, Red Cross Society, Program for Belize, Iwokrama, CARIBSAVE
- International development community
    - E.g. FAO, UNDP, UNEP, IDB, World Bank, Advisory Group on Climate Finance
- Other regional / international entities
    - E.g. ACS, AOSIS, OAS, UNFCCC Secretariat, CDEMA ASSC / TMAC, UNGA

On the regional geographic scale of this study and the IP, it is to the CARICOM ministerial bodies and organisation that many countries look to for support, and often leadership in technical matters. Even this list is long and variable by circumstance, but the IP identifies the following by interest in addition to the lead three already mentioned:

- CARICOM Secretariat (CARISEC)
- Council of Trade and Economic Development (COTED)
- Council for Human and Social Development (COHSOD)
- Council for Foreign and Community Relations (COFCOR)

- Caribbean Tourism Organisation (CTO)
- Caribbean Development Bank (CDB)
- Caribbean Environmental Health Institute (CEHI)
- Caribbean Institute for Meteorology and Hydrology (CIMH)
- Caribbean Agricultural Research and Development Institute (CARDI)
- Organisation of Eastern Caribbean States (OECS)
- University of the West Indies (UWI)

The interests of each in fisheries, aquaculture, CCA and DRM are varied and situation specific. Often they may depend in part on cross-sectoral and transboundary initiatives such as in the way fisheries and aquaculture are included in (often more in theory than practice) the regional agricultural agenda. Of particular interest in this respect is the Jagdeo Initiative that may give effect to CARICOM's 1996 Regional Transformation Programme and successor 2001 Community Agricultural Policy. The Jagdeo Initiative contains a vision for agriculture in 2015 to be realised by the removal of key binding constraints to agricultural development through strategic action[23].

International actors must, however, not be overlooked. Development and donor organisations are playing key roles in shaping approaches to CCA and DRM in the CARICOM region. For example, the FAO has had a series of projects to develop national level plans for DRM in the agriculture sector that usually includes small-scale fisheries and aquaculture. There are several initiatives involving USAID, UNDP, UNEP, IDB, JICA, GEF, GIZ and many more. While few focus primarily upon aquatic systems, most are relevant from ecosystem and institutional perspectives. Recalling the CCCCC database of over 300 CCA projects in the region as of 2010, there has clearly been an increase in CCA and DRM initiatives. Several of these projects involve civil society partnerships at regional, national and local levels. TNC, CANARI and GFC are examples from each of the levels. Updating and maintaining the database would be extremely useful, but a difficult task unless all relevant state and non-state actors submitted project meta-data on a regular basis to CCCCC.

Given our perspective on livelihoods the institutional arrangements of actors and interests at national and local levels are particularly important to first understand and to then manage. Figure 2.9 illustrates some of the actors, but does not draw lines (links) among them as this is best accomplished through network analysis. Network maps will change over time and with situations as previously mentioned. Keeping track of multi-level linkages and especially those that seem to favour success while reflecting good governance and best practices is important for learning to institutionalise adaptation.

[23] Vincent Little offers an insightful analysis including a series of reasons for slow or low key implementation http://www.ecdpm.org/Web_ECDPM/Web/Content/Download.nsf/0/CA088E5BAD6D7CA4C1257501002F0E27/$FILE/Little_Vincent_AIDAND%20TRADE%20PRESENTATION%20%5BCompatibility%20Mode%5D.pdf accessed 20 Jul 12

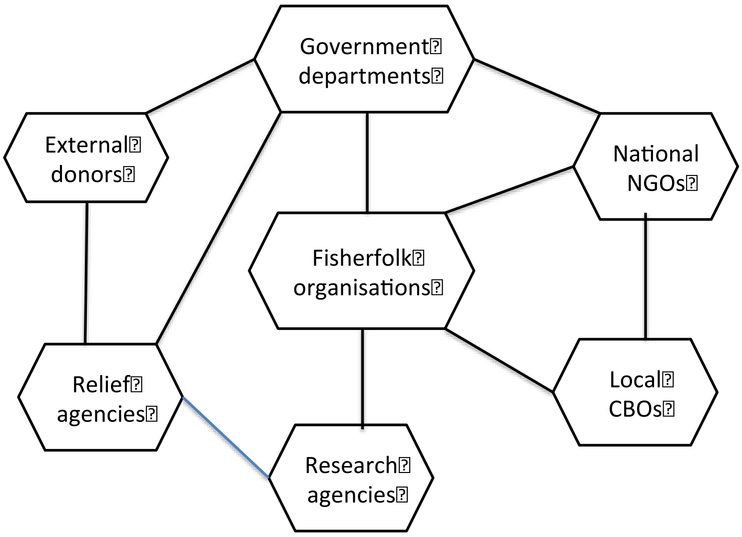


Figure 2.9 Key national and local level stakeholders in CCA and DRM are often networked

2.4 Themes, trends and linkages

A country or sector's adaptation and management responses should be formulated as part of broader policies and plans for sustainable development, including those not directly related to climate change and disasters[24]. There is considerable guidance available on mainstreaming climate change adaptation and disaster risk management cross-sectorally from different entry points and at different levels of intervention[25]. Prevailing themes and trends include linkages to the Millennium Development Goals (MDGs), low carbon economies and green economy initiatives among many. There are also enduring cross-cutting themes such as gender and poverty to consider. Early screening of interventions can assist in ensuring that optimal cross-sectoral benefits are aimed for and multiple objectives are achieved[26]. The use of screening tools makes the trade-offs among competing, and sometimes conflicting, aims and objectives more explicit and transparent, facilitating better decision-making.

Two of the prime reasons for paying considerable attention to themes, trends and linkages concern strategically mobilizing resources and undertaking monitoring and evaluation (M&E) effectively and efficiently. Chapters 3 and 10 of the IP make this abundantly clear. In fisheries management, the global focus is clearly on conservation rather than development given the prevalence of overfishing. For SIDS in the Caribbean the opportunities for international financing of fisheries are generally shrinking unless concerns that are higher priority in the international arena, such as CCA and DRM, are addressed. The financing situation is not as dire for aquaculture which is seen as having more investment and growth potential but, from an ecosystem services perspective, Caribbean SIDS have

[24] UNDP. 2004. Adaptation Policy Frameworks for Climate Change. Cambridge, UK: Cambridge University Press.

[25] UNDP-UNEP. 2011. Mainstreaming Adaptation to Climate Change into Development Planning: A Guide for Practitioners. UNDP-UNEP Poverty-Environment Initiative. Available from: http://www.unpei.org/knowledge-resources/publications.html

[26] Olhoff, A. and C. Schaer. 2010. Screening Tools and Guidelines to Support the Mainstreaming of Climate Change Adaptation into Development Assistance – A Stocktaking Report. UNDP: New York.

difficult choices when allocating coastal areas to aquaculture where biodiversity conservation and environmental management are common issues. Fitting responsible fisheries and aquaculture interventions within CCA and DRM will be beneficial for funding the programme proposal.

Regarding M&E, there are numerous indicator schemes already developed in support of international goals and initiatives such as the MDGs and marine protected areas (MPAs), for example. Linking the indicators for fisheries and aquaculture CCA and DRM to sets that are already approved and are being used is beneficial on many fronts. It facilitates integration into cross-sectoral policies and agendas, and may efficiently utilize resources for measurement and reporting, for example. There is only modest use of indicators in the programme proposal. Much more groundwork is required to develop robust indicators, since programmes and projects may span several areas or countries not yet decided.

A vital link alluded to earlier is that between CCA and DRM. The IP (see Chapter 7) sets out the relationships by mapping both the conceptual and operational intersections in a series of tables that are reproduced below. Although the IP refers to DRR more often than DRM, the distinction is blurred as evidenced by the contents of Table 2.1 that outlines common ground. As previously mentioned, the zone of convergence between these is increasing. Common elements include attention to forecasting, poverty, development and local level human impacts.

Table 2.1 Summary taken from the IP of commonalities between CCA and DRR / DRM (Source: CCCCC 2012)

COMMON AREAS	**EXPLANATION**
Influence of poverty, and vulnerability and its causes	The severity of the conditions caused by climate change and disasters is influenced by poverty and by vulnerability and its causes
Vulnerability reduction focused on enhancing capacity, including adaptive capacity, and devising responses in all sectors	Assessing risk vulnerability is fundamental to both subjects Reducing vulnerability requires multi-stakeholder participation
Integration in development	Both must be integrated into development plans and polices
Local level importance	Measures to relieve risk and adapt to climate change must be effective at the local level
Emphasis on present day conditions	Increasingly it is recognized that the starting point is in current conditions of risk and climate variability (i.e. ‘no regrets’)
Awareness of need to reduce future impacts	Despite a tradition based on historical evidence and present day circumstances, the aim of disaster risk reduction to build resilience means that it cannot ignore current and future climate change risks
Appropriateness of non-structural measures	The benefits of non-structural measures aid both current and less well understood future risk reduction needs
Full range of established and developing tools	For example: early warning systems; seasonal climate forecasts and outlooks; insurance and related financial risk management; building design codes and standards; land-use planning and management; water management including regional flood management, drainage facilities, flood prevention and flood-resistant agricultural practices; and environmental management, such as beach nourishment, mangrove and wetland protection, and forest management
Converging political agendas	At the international level, the two policy agendas are increasingly being discussed together, including through the Bali Action Plan (decision 1/CP.13) and the Hyogo Framework for Action

The IP specifically pays attention to the synergistic overlap with the Enhanced CDM Framework of CDEMA and particularly Outcome 4, which is "Enhanced community resilience in [CDERA] states/ territories to mitigate and respond to the adverse effects of climate change and disasters" (Table 2.2).

Table 2.2 Linkages envisaged in the IP between the CDM and the Regional Framework (Source: CCCCC 2012)

CDM FRAMEWORK OUTCOME 4 COMPONENT OUTPUTS			
OUTPUT 4.1, Preparedness, response and mitigation capacity (technical and managerial) is enhanced among public, private and civil sector entities for local level management and response	OUTPUT 4.2, Improved coordination and collaboration between community disaster organizations and other research/ data partners including climate change entities for undertaking comprehensive disaster management	OUTPUT 4.3, Communities more aware and knowledgeable on disaster management and related procedures including safer building techniques	OUTPUT 4.4, Standardized holistic and gender sensitive community methodologies for natural and anthropogenic hazard identification and mapping, vulnerability and risk assessments, and recovery and rehabilitation procedures developed and applied in selected??
RELATED GOALS OF THE REGIONAL FRAMEWORK			
Goal 1.2, Reduce Vulnerability to a changing climate	Goal 3.1, Effectively access and utilize resources to reduce vulnerability to a changing climate	Goal 1.4, Build a society that is more informed about and resilient to a changing climate Goal 2.2, Promote the implementation of measures to reduce climate impacts on coastal and marine infrastructure Goal 2.3, Promote the adoption of measures and dissemination of information that would adapt tourism activities to climate impacts	Goal 1.1, Assess the vulnerability and risks associated with a changing climate

CDEMA has addressed the mainstreaming of CCA into DRR/DRM (CCA2DRR[27]) and offers the Guidance Tool (G Tool) that in seven steps (Figure 2.10) provides:

- An orientation on climate, climate change, disaster risk and adaptation
- A method for undertaking the mainstreaming process

[27] CDEMA. 2011. The Guidance Tool: A Manual for Mainstreaming Climate Change Adaptation into the CDM Country Work Programme. Caribbean Disaster Emergency Management Agency, Barbados.147pp

- Tools for stakeholder identification, impact identification and adaptation mainstreaming
- Caribbean climate hazard case studies
- Reference information on useful documents, manuals, and guidelines
- Prepared presentations

The G Tool seeks to establish an operational linkage at the national level between the region's CDM initiatives coordinated by CDEMA and the region's climate change adaptation initiatives coordinated by the CCCCC (CDEMA 2011)

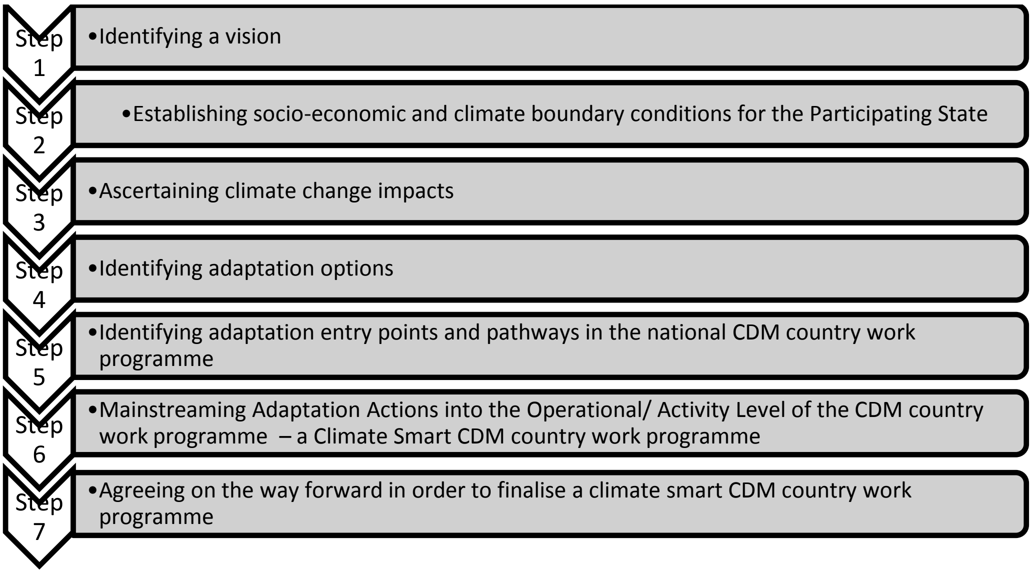


Figure 2.10 Steps in the G Tool CCA2DRR process
(Adapted from CDEMA 2011)

The main cross-cutting components that connect the IP with CDM are shown in Table 2.3 highlighting the desired results of such integration.

Table 2.3 Programme areas identified in the IP for integrating CCA and DRR/DRM
(Source: CCCCC 2012)

PROGRAMME CROSS CUTING COMPONENTS	DESIRED RESULTS
Institutional structure and governance	• Existing structures strengthened by integrating and mainstreaming climate change into the existing disaster management framework. • Improved national climate change adaptation frameworks.
Legislation	• Model Climate Change Legislation- model legislation on Climate Change produced which factors in specific considerations in disaster risk reduction. • Regional Standards - regional standards produced which factor in climate change considerations in disaster risk reduction measures for hazard mapping and risk assessment. • Guidelines - regional guidelines produced which factor in climate change considerations in disaster risk reduction measures for building and infrastructure.
Capacity building	• Planning and national / local emergency organizations agencies' have an increased understanding of the impact of not reducing risk on

PROGRAMME CROSS CUTING COMPONENTS	DESIRED RESULTS
	sustainability, and increased in their ability to implement and enforce development standards.
Data sets / database	• Improved accessibility of consolidated data related to DM and CC.
Information and targeted communication	• Revised CCCCC Climate Change Public Education and Outreach Strategy and CDEMA Model Education Strategy that includes intersection of CC and DRR. • The implementation of the information and communications strategy.
Research	• Research into best practices and documentation for regional implementation of climate change adaptation and disaster risk reduction. • Research in the use of remote sensing in disaster risk management (case studies and new technology). • The use of existing radars for real time flood forecasting (DRM). • Improvement of existing climate models.
Training and education	• Coordination of training programmes and opportunities to achieve more efficient use of scarce resources and the minimisation of duplication. • Establish standardised training programmes for the region through a suite of DRM & CC courses; as well as the development of a timetable of available courses. • Create and award undergraduate degrees in DRM including climate change. • Sensitise all students, regardless of discipline, to DRM & CC.
Monitoring and evaluation	• Develop a monitoring and evaluation framework by adapting the existing M&D framework that was developed under the CDEMA / IDB Tourism project for use at national level. • Improve information sharing using existing websites to allow interested national actors to have access to project documents, information and outputs from CC & DRM projects. • Establish instrumentation / technology to monitor hazards, including forecasting, early warning system(s) and projections.

CDEMA has also set out schematically how it anticipates the convergence and integration of the CARICOM frameworks for climate and disasters to occur, progressing from the regional to local level through the use of the G Tool in relation to the IP (Figure 2.11).

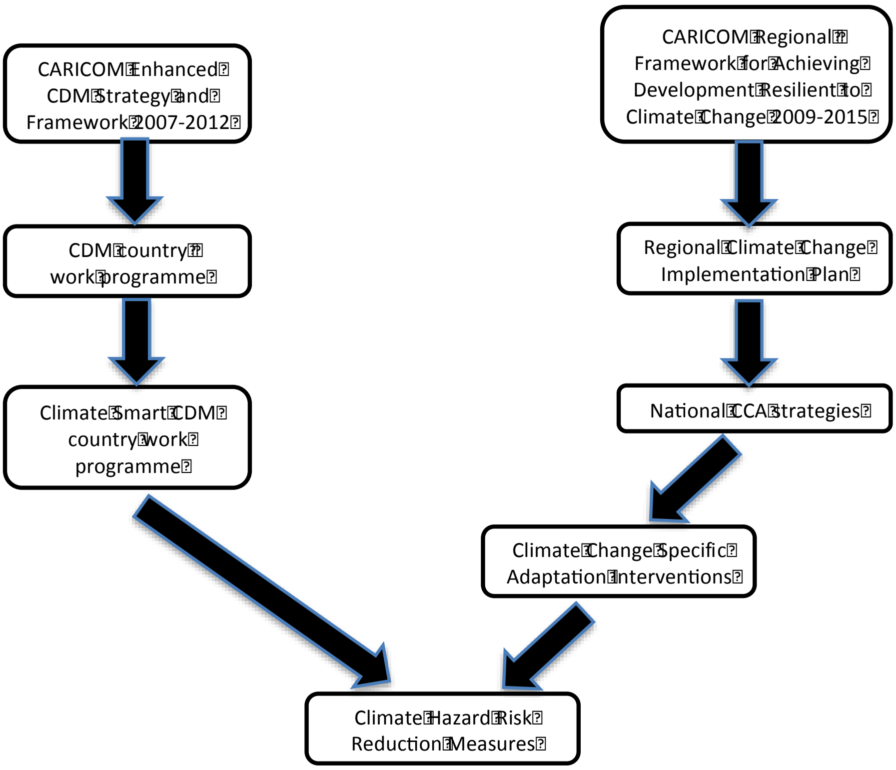


Figure 2.11 The functional relationship between the G tool and the IP (Adapted from CDEMA 2011)

In similar vein to the G Tool, the OECS has developed a Disaster Risk Management Benchmarking Tool (the B-Tool)[28] in cooperation with CDEMA and USAID. Goal of the B Tool is to improve the ability of communities, national governments, civil society organizations, and the private sector to proactively plan and implement actions to reduce vulnerability to natural disasters and create greater economic resilience when they do occur. It can be used to validate that disaster risk management tasks have been completed and resources are available, to report on the status of their readiness and to prepare a list of items or tasks to be checked or consulted when investing in DRM. The OECS is also developing a harmonized protocol for integrating DRR and DRM into the national environment management strategies NEMS of its member states. This provides sub-regional to national linkages.

There have been several large regional, sub-regional and national projects addressing climate and disasters (recall the CCCCC database mentioned earlier). Indeed, the number of such projects and programmes appears to be increasing. Some of these are integrated or coordinated, but several are stand-alone. The reader may wish to be aware of the following among the several hundred projects:

- Adaptation Activities to Increase Resilience and Reduce Vulnerability to Climate Change Impacts in the Eastern Caribbean Fisheries Sector (ARCCIF)
- Adapting to Climate Change in the Caribbean (ACCC)
- Caribbean Hazard Mitigation Capacity Building Program (CHAMP)
- Caribbean Planning for Adaptation to Global Climate Change (CPACC)
- Caribbean Risk Management Initiative (CRMI)
- CARIBSAVE Climate Change Risk Atlas
- Disaster Mitigation Facility for the Caribbean (DMFC)

[28] Spatial Systems Caribbean Ltd. 2006 Disaster Risk Management Benchmarking Tool (B-Tool). Prepared for USAID and OECS.

- Disaster Vulnerability and Climate Risk Reduction Project (DVRP)
- FAO review of the status of development and implementation of Disaster Risk Management plans for the agriculture sector
- Mainstreaming Adaptation to Climate Change (MACC)
- Mainstreaming Climate Change into Disaster Risk Management (CCDM)
- Managing Adaptation to Environmental Change in Coastal Communities: Canada and the Caribbean (C-CHANGE)
- Pilot Program for Climate Change Resilience (PPCR)
- Reduce the Risks to Human and Natural Assets Resulting from Climate Change (RRACC)
- Special Programme for Adaptation to Climate Change (SPACC)
- Tsunami and Coastal Hazards Warning System

Several of the above projects and relationships will be returned to in the strategy and action plan, and in the programme proposal. The main point here is that readers should be aware of the close linkages and existing substantial groundwork. Much has already been set up that is suitable for fitting fisheries and aquaculture. Before returning to this we take a summary look at what we know about these topics.

3 OVERVIEW OF CLIMATE CHANGE AND DISASTERS IN THE CARIBBEAN

3.1 Key conditions and evidence

The Caribbean region is characterized a cool-dry winter/hot-wet summer climate regime. The temperature pattern generally follows the motion of the sun, with some spatial variation across larger islands, as coastal areas exhibit warmer temperatures compared to the cooler (oftentimes mountainous) interiors of the islands. Sea breezes and the warm ocean temperatures of the Gulf and Caribbean Sea also help modulate temperatures year round.

Peak rainfall occurs in the latter half of the year for most Caribbean islands, coinciding with peak hurricane activity. In some islands there is bimodality to the rainfall pattern, with an early rainfall period (May / June), followed by a brief dry period and then the primary rainfall period. By virtue of its location, the region is also prone to the influence of hurricanes, which pass through the north tropical Atlantic.

On the seasonal time scale, the Caribbean rainfall regime is conditioned by the large-scale features of the tropical north Atlantic. Rainfall received during the dry early months reflects the influence of North American frontal systems, which trek through the northern Caribbean. The onset of the rainfall season is marked in early spring by the northward migration of the north Atlantic high pressure system which yields lower surface pressures and weaker trades across the Caribbean. The appearance of warm ocean surface temperatures and lower vertical shears in the wind field (especially in September - October) also enhances convective potential and therefore helps determine the onset, duration and peak of the wet season. The presence of surface, mid and upper level troughs and the passage of easterly waves, tropical depressions, storms and hurricanes then give rise to most of the rainfall.

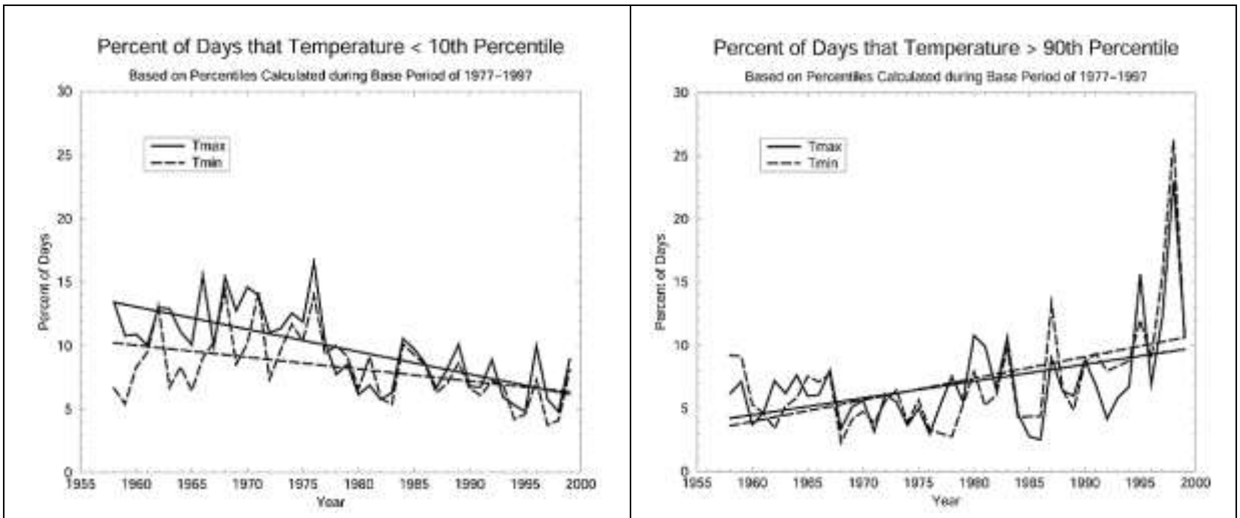
Global phenomena such as the El Niño Southern Oscillation (ENSO) also contribute to variability by altering the conditions suitable for rain. An El Niño generally creates unfavorable conditions for rainfall and hurricane development in the main Caribbean basin during the late season of the year of its occurrence, due to the stronger vertical shears it creates in the wind field[29]. Consequently drought occurrences in the region have been associated with El Niño episodes[30]. An El Niño however enhances rainfall potential and Caribbean surface temperatures during the early wet season of the year of its decline due to the warm ocean temperatures it induces in the north tropical Atlantic. Other global climatic phenomena which similarly influence interannual and decadal variability of Caribbean rainfall include the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO).

3.1.1 Temperature

An increasing trend in surface temperatures has been observed in the Caribbean historical record. Ten global climate indices were used to examine changes in extremes in Caribbean climate from 1950 to

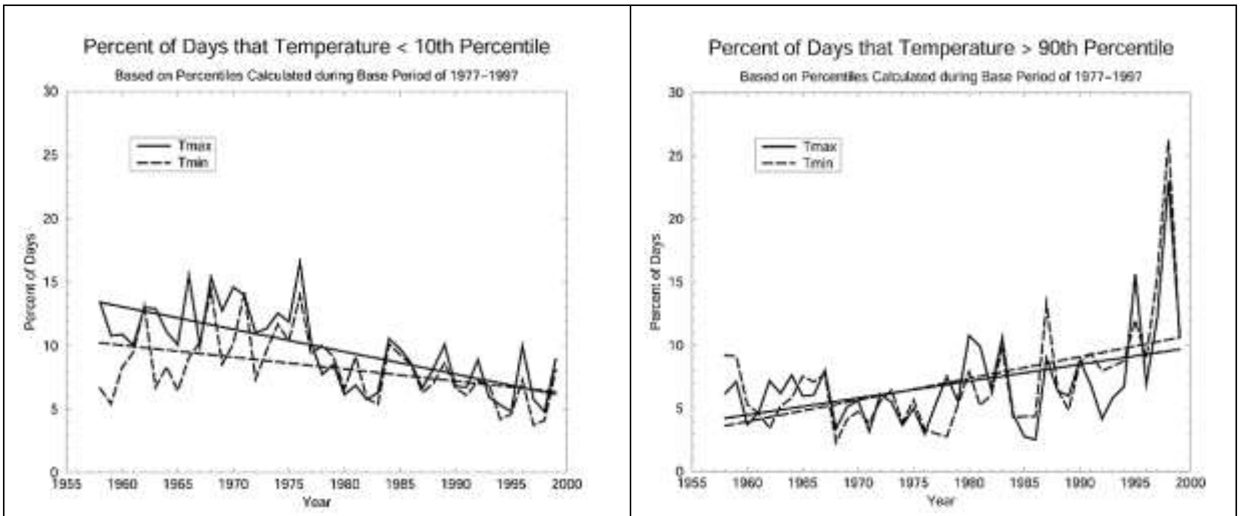
[29] Gray, W. M., C. W. Landsea, P. W. Milke Jr. and K. J. Berry. 1994. Predicting Atlantic Basin seasonal tropical cyclone activity by 1 June. Weather and Forecasting 9:103 - 115.
[30] Chen, A. A, and M. A. Taylor. 2002. Investigating the link between early season Caribbean rainfall and the El Niño+1 year. International Journal of Climatology 22:87 - 106

2000[31]. The difference between the highest and lowest temperature for the year (i.e. the diurnal range) is observed to be decreasing but is not significant at the 10% significance level. Temperatures falling at or above the 90th percentile (i.e. really hot days) are also increasing while those at or below the 10th percentile (really cool days and nights) are decreasing (both significant at the 1% significant level) (see Figure 3.1). These results indicate that the region has experienced some warming over the past fifty years.



(a) (b)

Figure 3.1).



(a) (b)

Figure 3.1 Temperature trends in the Caribbean. (a) The percent of days maximum (solid line) and minimum (dashed line) temperatures are at or above the 90th percentile. (b) Percent of days when maximum temperature (solid line) or minimum temperature (dashed line) are less than or equal to the 10th percentile. Percentiles determined by data from 1977 through 1997. (From Peterson et al. 2002)

[31] Peterson, T. C., Taylor M. A., Demeritte R., Duncombe D., Burton S., Thompson F., et al. 2002. Recent changes in climate extremes in the Caribbean region, J. Geophys. Res., 107(D21), 4601, doi:10.1029/2002JD002251

3.1.2 Precipitation

Precipitation over the islands in the Caribbean shows two distinct seasons in general: a dry season from November through April and a wet season from May through October[32]. Magnitudes vary considerably from the Bahamas to the southernmost islands of the Lesser Antilles and mountainous topography and its orientation with respect to the direction of trade winds further yield large spatial variations in precipitation on many islands.[33] A prominent feature of the seasonal cycle of precipitation is the mid summer drought (MSD)[34]. The MSD is not a real drought but a period during the wet season months when precipitation is relatively lower resulting in a bimodal cycle of precipitation. The timing and duration of the MSD vary across the Caribbean e.g. the MSD appears in early June in the eastern Caribbean and in late July around Cuba and the Bahamas and is non-existent in some of the eastern islands.

The seasonal cycle of precipitation in the western Caribbean is predominantly bimodal in nature with first maximum in precipitation in May or June and the second maximum between September and November. Jamaica, Haiti and Dominican Republic show precipitation peaks in May and October with a relative decrease in precipitation during the intermediate months. The double peak in precipitation can be seen at all latitudes in the western Caribbean with the second peak generally greater than the first. The seasonal cycle of precipitation over the islands in the eastern Caribbean similarly shows a bimodal cycle for most latitudes north of about 15^{o}N with the late season peak being greater than the first maximum. At latitudes south of 15^{o}N, however, there is only one peak which occurs late during the wet season and which is in part related to the Inter-tropical convergence zone (ITCZ) reaching its northernmost position in those months[35].

Notwithstanding, the islands of the Greater Antilles and the larger islands in the Lesser Antilles such as Dominica and Martinique show regional maxima in precipitation during the wet season months. Satellite data also suggest that many islands in the Lesser Antilles from Guadeloupe to St Lucia, receive considerably more precipitation than the surrounding waters. In addition to precipitation that results from mid-latitude air intrusions in the dry season[36], mountainous topography gives rise to orographic precipitation during the dry season months along the windward slopes of the islands. As a result, higher precipitation totals along the windward slopes and large spatial variations in precipitation from windward to leeward slopes are observed on these islands[37]. Dominica, in particular, shows over 2-3 mm/day precipitation throughout the year with a maximum of 10-12 mm/day in November. Precipitation over the Caribbean islands is more frequent than over the adjacent ocean during the wet season months due to land-sea thermal contrast. There is also a

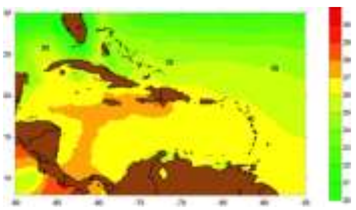
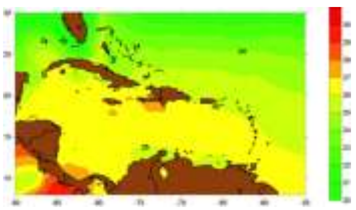
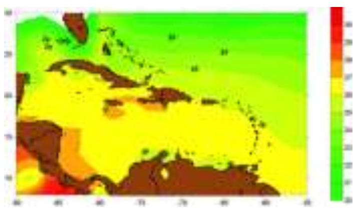
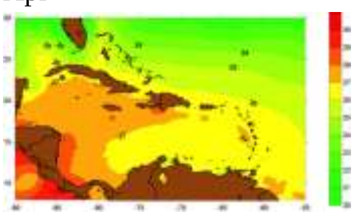
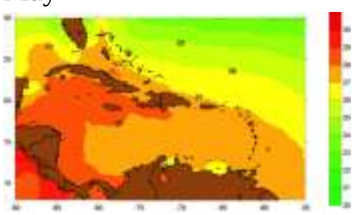
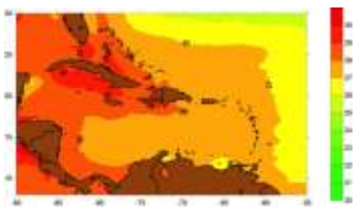
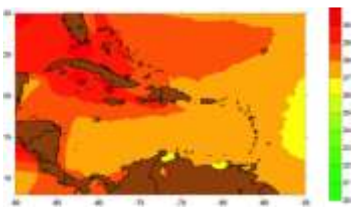
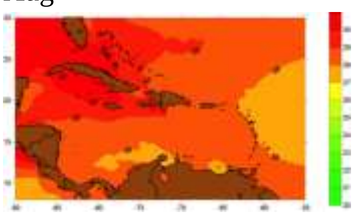
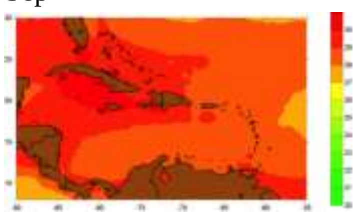
[32] Karmalkar A.V., M. A. Taylor, J. Campbell, T. Stephenson, M. New, A. Centella, A. Benzanilla, J. Charlery 2012. A Review of Observed and Projected Changes in Climate for the Islands in the Caribbean. Paper under review.
[33] Sobel A. H., C. D. Burleyson, S. E. Yuter, 2011. Rain on small tropical islands. *J Geophys Res* 116(D08102), doi: 10.1029/2010JD014695.
[34] Magaña V., J. A. Amador, S. Medina, 1999. The midsummer drought over Mexico and Central America. *J Clim* 12(6):1577 – 1588.
[35] Karmalkar et al 2012.
[36] Schultz D. M., W. E. Bracken and L. F. Bosart, 1998. Planetary- and synoptic-scale signatures associated with Central American cold surges. *Monthly Weather Review*, **126**, 5 - 27.
[37] Smith, R. B., P. Schafer, D. J. Kirshbaum, E. Regina, 2009: Orographic Precipitation in the Tropics: Experiments in Dominica. *J. Atmos. Sci.* **66**, 1698 – 1716.

significant increase in average island precipitation (relative to the ocean surrounding it) for large islands with mountainous topography[38].

3.1.3 Observed SST

Water temperatures within the Caribbean basin and neighboring Atlantic Ocean is possibly one of the most direct determinants of fisheries activities within the Caribbean region. However, historical data collected within that region has been extremely sparse. The best record available for observed sea surface temperatures provided by the Pathfinder's Advanced Very High Resolution Responder (AVHRR) which dates back only to 1985[39]. Figure 3.2 below, provides a monthly summary of sea surface temperatures averaged over the period 1985 to 2000. Data up to the present date are available, but have been separated from the 16 years average to serve as a control group for climate change models' comparison to be discussed later.

SST exhibits a cooler warm pool over the Western Caribbean during the early part of the year (Jan – Mar) of approximately 26.5°C (about 0.5°C warmer than the waters of the Eastern Caribbean. From April, the warm pool becomes progressively warmer to reach a maximum temperature of approximately 29.5°C in Sep/Oct in the area of Jamaica, Cuba and Hispaniola. During that time the warm pool progressively extends eastward, bringing temperatures of 28.5°C to the waters of the Eastern Caribbean by September. In the last three months of the year, the warm pool then progressively retracts back to the Western Caribbean, with sea surface temperatures then progressively cooling towards the lowest levels in March.

Jan 	Feb 	Mar 
Apr 	May 	Jun 
Jul 	Aug 	Sep 
Oct	Nov	Dec

[38] Karmalkar et al 2012.
[39] ftp://jerry.rsmas.miami.edu/pub/SST18km/

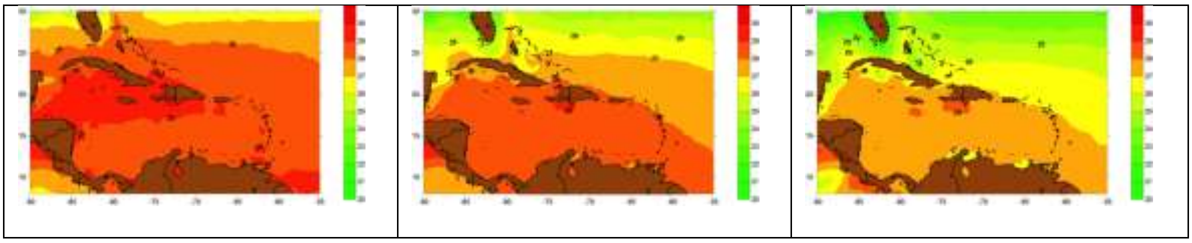


Figure 3.2 Observed monthly mean SST (1985-2000)

3.1.4 Hurricanes

Analysis of observed tropical cyclones in the Caribbean and wider North Atlantic Basin showed a dramatic increase since 1995. This increase however has been attributed to the region being in the positive (warm) phase of a multi-decadal signal and not necessarily due to global warming[40]. Results per year show that during the negative (cold) phase of the oscillation the average number of hurricanes in the Caribbean Sea is 0.5 per year with a dramatic increase to 1.7 per year during the positive phase. Attempts to link warmer sea surface temperatures (SSTs) with the increased number of hurricanes have proven to be inconclusive[41]. While SSTs in tropical oceans have increased by approximately 0.5℃ between 1970 and 2004, only the North Atlantic Ocean shows a statistically significant increase in the total number of hurricanes since 1995[42].

In an analysis of the frequency and duration of the hurricanes for the same time period, significant trends were again only apparent in the North Atlantic. Both frequency and duration display increasing trends significant at the 99% confidence level. There was almost doubling of the category 4 and 5 hurricanes in the same time period for all ocean basins[43].

3.2 Enhancing our understanding

A major control of seasonal precipitation in the Caribbean is the pressure gradient determined by the North Atlantic Subtropical High (NASH) and the equatorial low-pressure band. Whereas SSTs control organized convection, the sea level pressure (SLP) variability controls the magnitude and direction of the trade winds in the Caribbean[44].

Studies have demonstrated that the seasonal movement and changes in the intensity of the NASH are intimately linked to changes in precipitation through its relation to SSTs and influence on winds[45]. Lowest SLPs generally help to define the wet season months except for July and August when SLPs increase, particularly in the western Caribbean, due to a brief intrusion of the NASH. Precipitation peaks again when the SSTs reach their maximum values and SLP its minimum value of the year for given latitudes. The seasonal cycle of SSTs in the Caribbean Sea has only one peak during late summer (see Figure 3.2) unlike the precipitation seasonal cycle, but the seasonal cycle of local SLP

[40] Goldenburg, S. B., Landsea C., Mestas-Nuñez, A. M. & Gray, W. M. 2001. The recent increase in Atlantic hurricane activity: Causes and implications. Science 293:474 - 479

[41] Peilke Jr, R. A., C. Landsea, M. Mayfield, J. Laver and R. Pasch. 2005. Hurricanes and global warming. Bull. Amer. Meteor. Soc. 86:1571 - 1575.

[42] Webster, P. J., Holland, G. J., Curry, J. A., Chang, H. R. 2005. Changes in tropical cyclone number, duration and intensity in a warming environment. Science 309:1844 - 1846

[43] Webster et al. 2005.

[44] Karmalkar et al 2012.

[45] Wang C., S.-K. Lee and D. B. Enfield, 2008. Climate Response to Anomalously Large and Small Atlantic Warm Pools during the Summer. *J. Clim* 21, 2437 - 2450.

has two peaks. SLP peaks in boreal winter (the dry season) and again during mid-summer and is associated with peak intensities in easterly trade winds in the Caribbean Sea. This latter feature is commonly known as the Caribbean Low-Level Jet (CLLJ), which is essentially the intensified easterly trade winds along the southern flank of the NASH resulting from a large meridional pressure gradient in the region[43].

The CLLJ also has a bimodal seasonal cycle with maxima in July and February associated with the movement of the NASH and heating over the tropical South America. A number of studies note a strong negative correlation between Caribbean precipitation and the strength of the CLLJ[46]. An increase in the CLLJ intensity in July is associated with a decrease in precipitation, whereas a minimum in CLLJ strength in Oct-Nov coincides with peak precipitation in the region.

3.3 Forecasting the future

Many of these studies use coarse-resolution global climate models included in the fourth assessment report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) to describe large-scale climatic changes in the region[47]. More recently, a handful of studies have used high-resolution regional climate models (RCM) for studying climate change and its impact at spatial scales relevant for the islands[48] [49] [50].

For this report, a subset of available model data (GCM and RCM) was used to generate the future climate of the Caribbean region. Because Caribbean station data are sparse, a heavy reliance is placed on gridded datasets to examine the nuances of present-day Caribbean climate e.g. key features and spatial variability.

Historical temperature trends for the Caribbean have been shown to match global change. The intra-annual extreme range has been decreasing slightly although the trend is not significant[51]. In part, the decrease is attributed to increased cloud cover at night which leads to back radiation and the heating of the land. Maximum temperature is increasing with the trend significant at the 1% level. This warming is related to warmer sea surface temperatures (SSTs), though local SSTs only account for 25% of variance. The upward trend in minimum temperatures is significant at the 1% level and, as with maximum temperatures, linked to changes in SSTs, though the correlations are weaker and negative[52].

Precipitation in the Caribbean is dominated by variability on annual and decadal scales and matches the global average changes. It is most closely related to SSTs in the South Caribbean Sea, and

[46] Taylor M. A., F. S. Whyte, T. S. Stephenson and J. D. Campbell, 2012. Why Dry? Investigating the future evolution of the Caribbean Low Level Jet to explain projected Caribbean drying. *Int. J. Climatol.* doi: 10.1002/joc.3461.

[47] Biasutti M., A. H. Sobel, S. J. Camargo and T. T. Creyts, 2012. Projected changes in the physical climate of the Gulf coast and Caribbean. *Climatic Change* **112**, 819 - 845.

[48] Charlery J. and A. Nurse, 2010. Areal downscaling of global climate models: an approach that avoids data remodeling. *Climate Resear*ch 43: 241 - 249. doi: 10.3354/cr00875.

[49] Centella A., A. Bezanilla and K. Leslie, 2008. A Study of the Uncertainty in Future Caribbean Climate Using the PRECIS Regional Climate Model. Technical Report, Belmopan, Caribbean Community Climate Change Centre (CCCCC).

[50] Campbell J. D., M.A. Taylor, T. S. Stephenson, R. A. Watson and F. S. Whyte. 2010. Future climate of the Caribbean from a regional climate model. *Int. J. Clim*, doi: 10.1002/joc.2200

[51] Peterson, T. C., et al. 2002. Recent changes in climate extremes in the Caribbean region, J. Geophys. Res., 107(D21), 4601, doi:10.1029/2002JD002251

[52] Peterson et al. 2002

somewhat to the tropical North Atlantic SSTs. The Caribbean is dryer by 1-12 mm per month or 5-30% of rainfall per 100 years with a trend that is significant at 5% level[53]. Other studies show a decrease in precipitation across the Caribbean, with the exceptions being Bahamas, Venezuela and one of Trinidad's stations[51]. The simple daily intensity index shows a slight decrease, and although the trend is not significant, it correlates well with intense hurricanes at 0.41. Maximum precipitation (95th percentile and above) is increasing, but it is not significant at the 10% level, probably due to the inter-annual and decadal variability. The correlation with SSTs is good at 0.5. The greatest 5 day rain total is increasing with a significant trend at the 10% level and also displays significant inter-annual variability. The SST correlation is, however, not as large at 0.3. The number of consecutive dry days has decreased and the trend is significant at the 1% level[54]. Additionally, satellite precipitation data show a drying trend between June and August in the Caribbean in the last few decades.

Other variables are not easily available across the Caribbean for long time periods and as such their trends have yet to be seriously studied.

3.3.1 Temperature

In the initial projections for climate change projections for the Caribbean from a regional model showed a Caribbean which is 1°C to 5°C warmer in the annual mean by the 2080s (a 30-year period from 2071 to 2100) and conclude that: (a) a greater warming will occur in the northwest Caribbean territories (Jamaica, Cuba, Hispaniola and Belize) than in the eastern Caribbean island chain; and (b) a greater warming is observed in the summer months than in the cooler and traditionally drier early months of the year[55].

Incorporating the ECHAM forced runs i.e. considering also different GCM influences in addition to the changes related to greenhouse gases emission scenarios, has provided an improvement to this analysis[56]. Over the land areas, the annual warming is projected to be generally of the order of 4.5°C for the A2 scenario and 2.8°C for the B2 scenario. On the other hand, over the Caribbean Sea the annual warming is nearer 2.9°C (2°C) for the A2 (B2) scenario.

3.3.2 Precipitation

IPCC scenarios of percentage precipitation change for the Caribbean are also based on the multi-model data set (MMD) (Figure 3.3) and are also summarised in Table 3.1 for the A1B scenario[57]. The large value of T for precipitation (column 14) implies a small signal-to-noise ratio. In general, then, the signal-to-noise ratio is greater for temperature change than for precipitation change, implying that the temperature results are more significant. In other words, it takes a long time for the change in precipitation to become significant.

[53] Neelin, J. D., Munnich, M., Su, H., Meyerson, J. E., & Holloway, C. (2006). Tropical drying trends in global warming models and observations. Proc. Nat. Acad. Sci., 103, 6110 - 6115.
[54] Peterson et al. 2002
[55] Taylor, M. A., Centella, A., Charlery, J., Borrajero, I., Bezanilla, A., Campbell, J., Rivero, R., Stephenson, T. S., Whyte, F., Watson, R. 2007. Glimpses of the Future: A Briefing from the PRECIS Caribbean Climate Change Project, Caribbean Community Climate Change Centre, Belmopan, Belize. 24 pp.
[56] Centella et al 2008.
[57] Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton, 2007: Regional Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

From Table 3.1, most models project decreases in annual precipitation, with a few suggesting increase. Generally, the change varies from –39 to +11%, with a median of -12%. Figure 3.3 shows that the annual mean decrease is spread across the entire region (left panels). In December, January and February (DJF), some areas of increases are evident (middle panels), but by June, July and August (JJA) the decrease is region-wide and of larger magnitude (right panels), especially in the region of the Greater Antilles, where the model consensus is strong (right bottom panels)[58]. The annual mean drying and that seen in summer are supported by regional modeling studies undertaken at UWI[59 60 61].

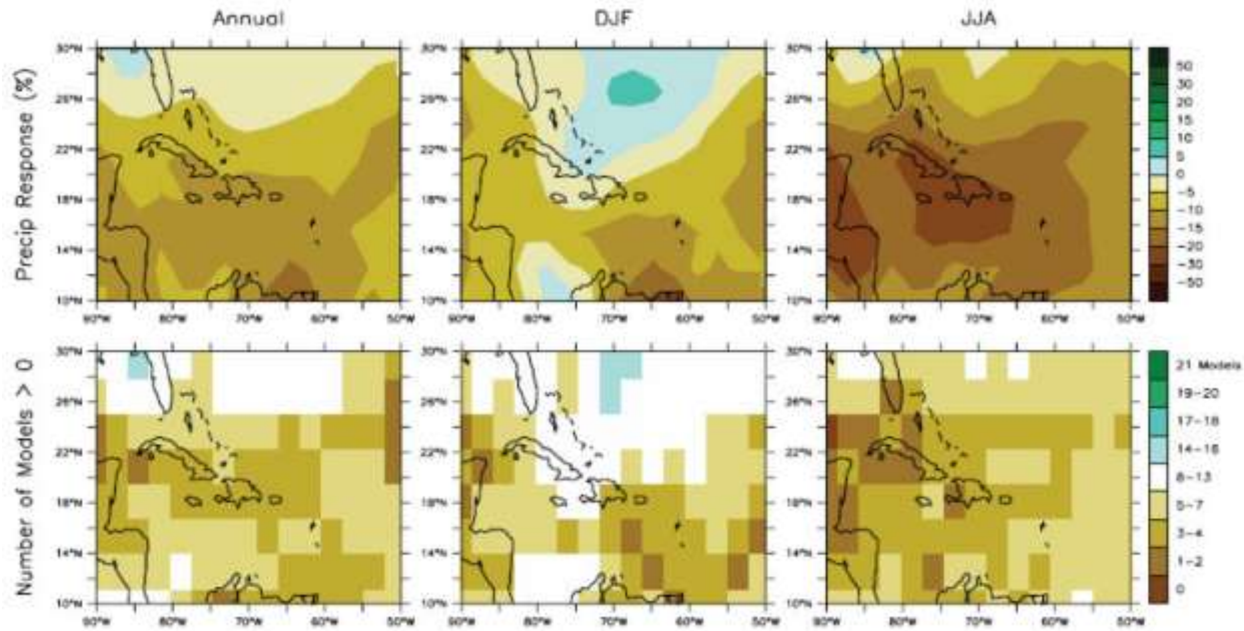


Figure 3.3 Precipitation changes over the Caribbean from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA fractional precipitation change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Bottom row: number of models out of 21 that project increases in precipitation. (From Christensen et al., 2007).

Table 3.1 Regional average of Caribbean (CAR) temperature and precipitation projections from a set of 21 global models in the MMD for the A1B scenario.

[58] Christensen et al. 2007.
[59] Cashman A., L. Nurse, and J. Charlery 2009 Climate Change in the Caribbean: The Water Management Implications. Journal of Environment and Development 19:42–67.
[60] Watson, R. A., M. A. Taylor, T. S. Stephenson and J. D. Campbell, 2008: Jamaica’s future climate deduced from climate models. Eighth Bi- annual Conference of the Faculty of Pure and Applied Sciences, University of the West Indies, Mona, February 26-28, 2008.
[61] Taylor et al 2007.

		Temperature Response (°C)						Precipitation Response (%)						Extreme Season (%)		
Region	Season	Min	25	50	75	Max	T yrs	Min	25	50	75	Max	T yrs	Warm	Wet	Dry
CAR 10N, 85W to 25N, 60W	DJF	1.4	1.8	2.1	2.4	3.2	10	-21	-11	-6	0	10		100	2	
	MAM	1.3	1.8	2.1	2.4	3.2	10	-28	-20	-13	-6	6	>100	100	3	18
	JJA	1.3	1.8	2.0	2.4	3.2	10	-57	-35	-20	-6	8	60	100	2	40
	SON	1.6	1.9	2.0	2.5	3.4	10	-38	-18	-6	1	19		100		22
	Annual	1.4	1.8	2.0	2.4	3.2	10	-39	-19	-12	-3	11	60	100	3	39

Table notes. The mean temperature and precipitation responses are first averaged for each model over all available realizations of the 1980 to 1999 period from the 20th Century Climate in Coupled Models (20C3M) simulations and the 2080 to 2099 period of A1B. Computing the difference between these two periods, the table shows the minimum, maximum, median (50%), and 25 and 75% quartile values among the 21 models, for temperature (°C) and precipitation (%) change. Regions in which the middle half (25 – 75%) of this distribution is all of the same sign in the precipitation response are coloured light brown for decreasing precipitation. T years (yrs) are measures of the signal-to-noise ratios for these 20-year mean responses.

The Hadley and ECHAM driven PRECIS simulations project large decreases in precipitation in the early wet season smooth out, to some degree, the bimodality in the western Caribbean's mean projections. However, the shape of the seasonal cycle remains mostly unchanged in the eastern Caribbean. The dry season experiences very little proportional decrease in precipitation in the Caribbean under the SRES A2 scenario, while there is a small increase in precipitation in November in the northwest Caribbean in the Bahamas.

Both RCM simulations project a decrease in precipitation in the early and late dry season, but the magnitude of change is very different with the Hadley driven RCM projecting much higher decrease than the ECHAM driven RCM. Projected changes in precipitation throughout the year are also very different in the two RCM simulations. The Hadley driven RCM projects year round decrease in precipitation in Jamaica and Hispaniola whereas the ECHAM driven RCM indicates small increases between November and January in this region. The Bahamas islands, in both RCM simulations, are projected to experience wetter conditions in the dry season. In the eastern Caribbean the agreement between the two RCM projections is less apparent[62].

3.3.3 SSTs Projections

Local SSTs in both the western and eastern Caribbean are projected by the ECHAM driven RCM to increase by about 2.4°C in the Eastern Caribbean to about 2.9°C in the western Caribbean by the 2080s relative to 1985 - 2000 mean from the pathfinder AVHRR, after the model's adjustment. Although the magnitudes are different, this spatial pattern of warming is consistent throughout the year. SSTs in the tropical North Atlantic and the Caribbean Sea are projected to increase less

[62] Karmalkar et al. 2012

compared to other tropical regions due to the influence of northeast trades[63] [64]. The A2 scenario of the ECHAM4 driven model is suggesting that the waters surrounding the Lesser Antilles are projected to warm at a higher rate compared to much of the Greater Antilles and the waters surrounding the Bahamas. Figure 3.3 provides an analysis of the mean monthly differences of the SRES A2 scenario SST in the Caribbean for the period 1985 - 2000 and the decade of the 2050s

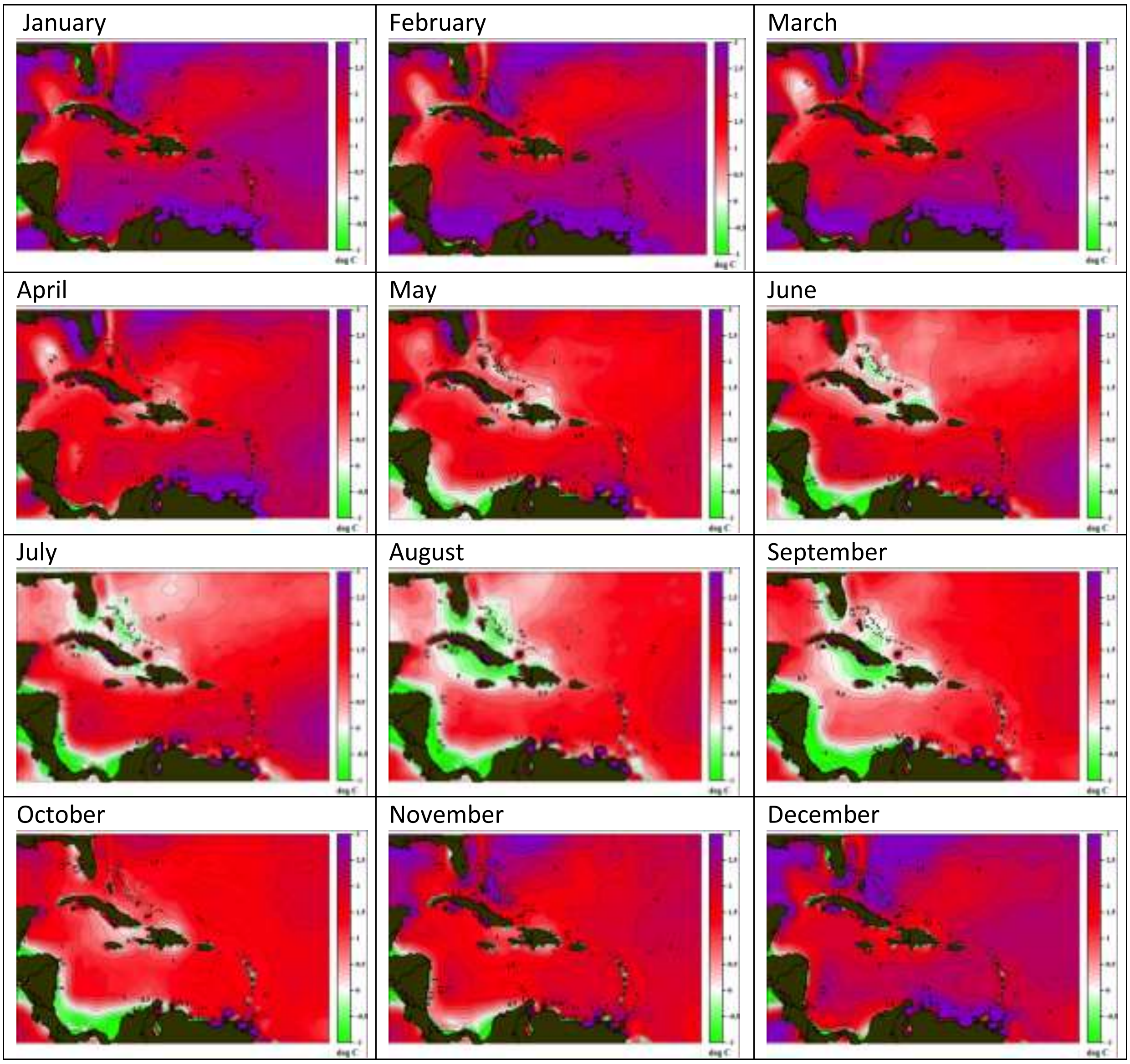


Figure 3.4 SRES A2 Difference in Caribbean SST from 1985-2000 mean from decades of 2050s

3.3.4 Hurricanes

While the number of intense hurricanes has been rising, the maximum intensity of hurricanes has remained fairly constant over the 35 year period examined. Results from high resolution global atmospheric model using time slice experiments for a present-day 10-year period and a 10-year period at the end of the 21st century under the A1B scenario, are generating tropical cyclones that now, more

[63] Vecchi G. A. and B. J. Soden, 2007. Global warming and the weakening of the tropical circulation. *J. Clim.* 20, 4316–4340, doi:10.1175/ JCLI4258.1.

[64] Leloup J. and A. Clement, 2009. Why is there a minimum in projected warming in the tropical North Atlantic Ocean?, *Geophys. Res. Lett.* **36**, L14802, doi:10.1029/2009GL038609.

closely, approximate real storms[65]. Tropical cyclone frequency decreased 30% globally, but increased by about 34% in the North Atlantic. The strongest tropical cyclones with extreme surface winds increased in number while weaker storms decreased. The tracks were not appreciably altered, and maximum peak wind speeds in future simulated tropical cyclones increased by about 14% in that model.

3.3.5 Sea Level Rise

Global sea level is projected to rise between the present (1980 – 1999) and the end of this century (2090 – 2099) by 0.35 m (0.23 to 0.47 m) for the A1B scenario[66]. Due to ocean density and circulation changes, the distribution will not be uniform. However, large deviations among models make estimates of distribution across the Caribbean uncertain. The range of uncertainty cannot be reliably quantified due to the limited set of models addressing the problem. The changes in the Caribbean are, however, expected to be near the global mean. This is in agreement with observed trends in sea level rise from 1950 to 2000, which were similarly near the global mean[67].

3.3.6 Evapotranspiration

The IPCC report does not address evapotranspiration specifically within the Caribbean. However, mean annual changes in evaporation for the SRES A1B scenario are given on a global scale in the report. It appears that by the end of the century (2080-2099) evaporation in the Caribbean will increase by about 0.3 mm / day-1 relative to current (1980-1999) values. It is to be noted that the evaporation value is given over the ocean as the models are too coarse to discern the small islands of the region, and as such evaporation over land may be less.

3.3.7 ENSO

IPCC models show continued ENSO inter-annual variability in the future. This suggests that extreme events (e.g. floods and droughts) associated with ENSO occurrences in the region are likely to continue in the future, even as their intensity and duration may be affected due to climate change. The idea is that even amidst an overall drying trend, short duration intense rainfall events may be just as or more likely in the future. There is, however, no consistent indication of discernible changes in projected ENSO amplitude and frequency in the 21st century[68].

3.3.8 Ocean acidification

According to the IPCC, the world's oceans have become approximately 30 per cent more acidic (i.e. a reduction in pH from 8.2 to 8.1units) since 1750 – the start of the Industrial Revolution. Projections

---

[65] Oouchi, K., J. Yoshimura, H. Yoshimura, R. Mizuta, S. Kusunoki and A. Noda. 2006. Tropical cyclone climatology in a global-warming climate as simulated in a 20km-mesh global atmospheric model: Frequency and wind intensity analyses. J. Meteorol. Soc. Japan, 84:259 – 276

[66] IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[67] Church, J. A., White, N. J., Coleman, R., Lambeck, K., Mitrovica, J. X. 2004. Estimates of the regional distribution of sea-level rise over the 1950 - 2000 period. J. Climate 17:2609 - 2625

[68] IPCC 2007

show the oceans becoming more acidic as carbon dioxide emissions continue to be absorbed[69]. Likely bio-physical impacts are not well understood, but could be significant for coral reefs, coralline algae and the skeletons or exoskeletons of some species, as well as the feeding and reproduction capacity of fish species[70]. This is one of the hazards with high uncertainty.

3.4 Summary

By mid-century, the picture of Caribbean climate, as deduced from models used, is one characterized by a decrease in wet season rainfall. The decrease is generally higher for the early wet season than for the late season and for the western Caribbean than for the eastern Caribbean. The intense early season drying tends to smooth out the bimodality of the western Caribbean, but the seasonal cycle of the eastern Caribbean remains unchanged. The dry season is largely unaltered except for a small increase in precipitation in November in the western Caribbean[71]. The simulations similarly project a drying (though more intense) for the wet season. The future picture is completed by higher warming of surface air temperatures over the northwestern Caribbean and relatively lower warming in the south-eastern Caribbean.

Another element, which bears noting, is the decrease in rain days, which corresponds with the frequency of high intensity rainfall events. This feature points to increased local storminess, surface runoff and erosion, especially in the small mountainous islands of the eastern Caribbean.

Finally, it should also be noted that the year to year variations in the seasonal cycle of the Caribbean climate parameters described above are largely dependent on climate variability in the eastern Pacific and the North Atlantic[70]. El Nino Southern Oscillation (ENSO) and the North Atlantic Oscillation have seasonally dependent influence on temperature and precipitation. Changes, then, in ENSO and NAO variability in the future will affect climate variability in the Caribbean[70]. However, the nature of ENSO and NAO variations in response to elevated levels of GHGs remains highly uncertain and is a limitation to examining future changes in inter-annual variability of Caribbean climate.

Based on the above, the following summary can be made about future climate conditions within the Caribbean.

1. Sea levels are likely to continue to rise on average during the century around the small islands of the Caribbean Sea. Models indicate that the rise will not be geographically uniform but large deviations among models make regional estimates across the Caribbean uncertain. The increase will probably follow the global average.

2. All Caribbean islands are very likely to warm during this century. The warming is likely to be somewhat smaller than the global annual mean warming in all seasons.

3. Summer rainfall in the Caribbean is very likely to decrease in the vicinity of the Greater Antilles but changes elsewhere and in winter are uncertain.

---

[69] Nurse, L. 2011. The implications of global climate change for fisheries management in the Caribbean. Climate and Development 3:228 - 241

[70] IPCC, 2011: Workshop Report of the Intergovernmental Panel on Climate Change Workshop on Impacts of Ocean Acidification on Marine Biology and Ecosystems. C.B. Field, V. Barros, T.F. Stocker, D. Qin, K.J. Mach, G.-K. Plattner, M.D. Mastrandrea, M. Tignor and K.L. Ebi (eds.)]. IPCC Working Group II Technical Support Unit, Carnegie Institution, Stanford, California, United States of America, pp. 164.

[71] Karmalkar et al. 2012

4. It is likely that intense tropical cyclone activity will increase (but tracks and the global distribution are uncertain).

5. Short term variability in rainfall patterns (e.g. as caused by ENSO events) will likely continue. The prevailing warmer conditions may make the convection associated with the short lived events more intense. In general, climate change will produce a warmer, dryer (in the mean) region with more intense hurricanes, and possibly more variability

4 FISHERIES AND AQUACULTURE SECTOR

Attention to CCA and DRM in fisheries and aquaculture in the Caribbean is new. We can learn from and perhaps adapt similar initiatives that have taken place elsewhere that seem reasonably similar. We can look, for example, at how such an investigation has been approached in the Pacific (Bell et al 2011). They point out that we need to appreciate, even if not fully understand, social-ecological linkages in order to make the most appropriate decisions on adaptation and management, often with limited data and high levels of uncertainty. Direct (usually ecological) and indirect (both social and ecological) pathways exist between climate change or variability and the potential impacts that may result in disasters. The pathways can be quite complex with multiple drivers and impacts. Since fisheries and aquaculture are social-ecological systems, ecological and socio-economic pathways and impacts can be expected (Figure 4.1)

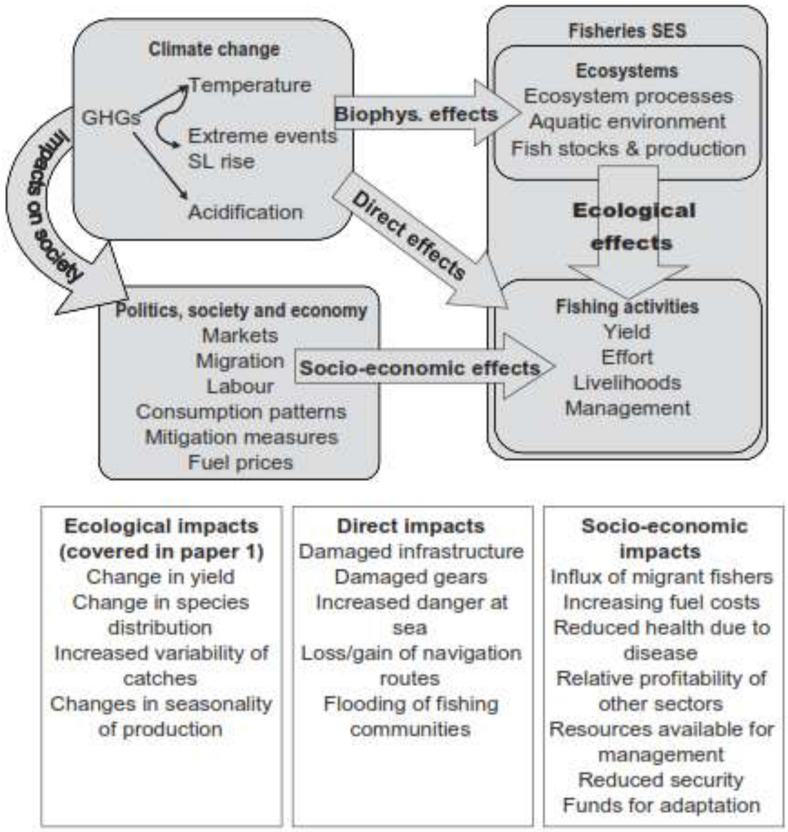


Figure 4.1 Ecological, direct and socio-economic impacts of climate change on fisheries and some examples of each (Daw et al 2009)

These pathways also have to be considered at different levels on different scales since not all interactions occur at the same time and in the same space. There may be lags in time and interactions that take effect in places that are distant from their origin. This produces very complex models, and their uncertainty increases as one extrapolates from global climate scenarios to impacts on social-ecological systems locally, where adaptation and management are crucial for livelihoods (Figure 4.2).

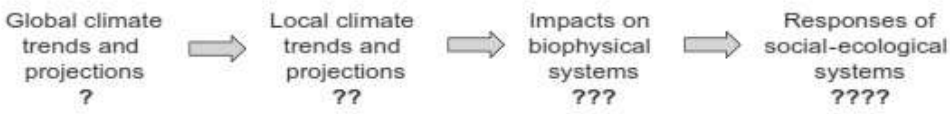


Figure 4.2 Increasing uncertainty along the pathway of impacts of climate change (Daw et al 2009)

These connected arguments suggest that, while global, regional, sub-regional and national contexts cannot be ignored, it is not unreasonable to attempt effective action at the local level where aquatic resource systems may be best understood especially in the light of past experience with climate variability and hazards. Adaptation and management at community, livelihood, household and enterprise local levels should be pursued even if there are deficiencies at higher levels. In order for this to occur, enabling policy that encourages self-organisation to reduce vulnerability and improve resilience is normally required. This is consistent with the livelihoods approach outlined earlier. A general framework that links climate to policies such as sustainable fisheries and food security[72] was proposed and discussed at regional workshop in 2002, but it has not been utilized (Figure 4.3.)

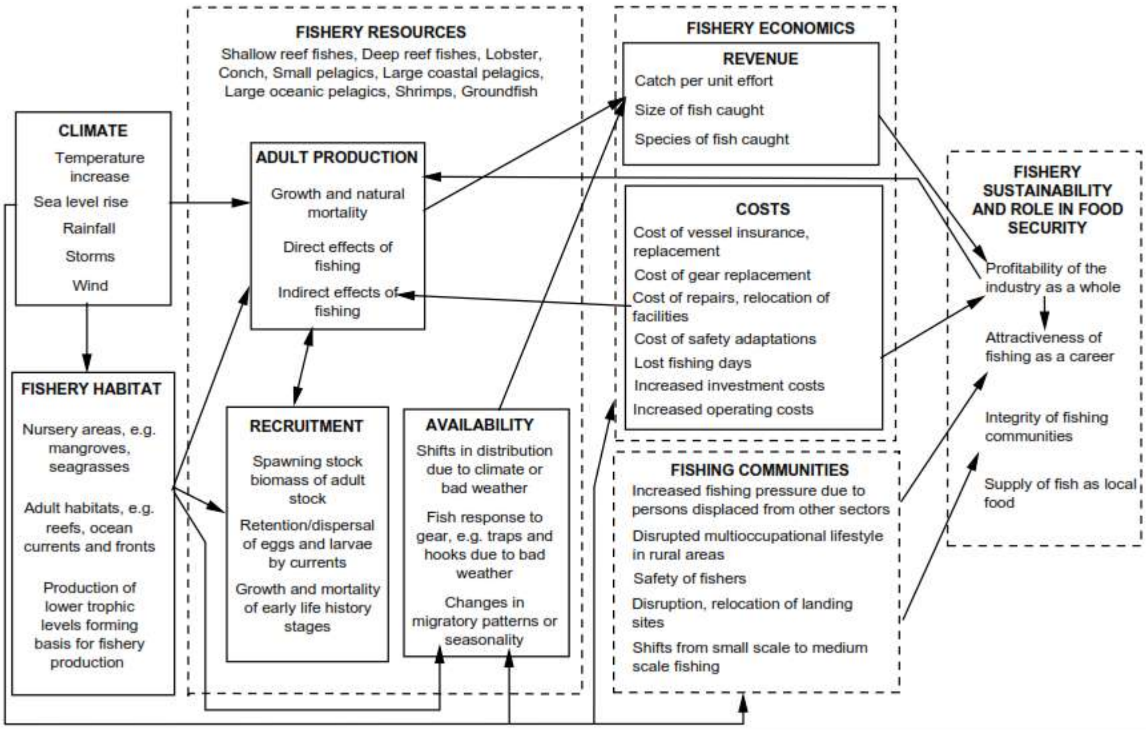


Figure 4.3 Framework for assessment of the impacts of climate change on the fisheries of CARICOM countries (Source: Mahon 2002)

This introduction sets the stage for a summary examination of climate and disasters in relation to Caribbean fisheries and disasters before the more critical matters of adaptation and management measures are addressed. Anticipated but uncertain changes in aquatic ecology; changes in the life cycles, distribution and abundance of species; changes in fisheries and aquaculture practices along the entire value chain and so on reduce the benefits of past and current knowledge unless the latter span the entire range of variability and new patterns do not vary much from the old. This limitation affects

[72] Mahon, R. 2002. 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

science and other formal knowledge systems as well as local and traditional knowledge. The aim of adaptation and risk management is not so much to rely on past experience as it is to prepare for new experiences proactively or by rapid response reactively.

In the next subsections we examine specific changes and hazards that do or may impact fisheries and aquaculture. There are several ways in which to do this. For readers involved in climate and hazards these would be the main headings, with the types of fisheries and aquaculture as secondary. However, for fisheries and aquaculture stakeholders (from managers to resource users) the tendency should be to address climate and hazards within (sub) regional or national policy and management plans. These policies and plans may be for entire ecosystems, for species or species groups that are targeted or cultured, for defined areas such as MPAs, or for specific practices such as gear or production types.

Over the past three decades the attempts to institutionalize fisheries management planning in CRFAMP / CRFM members has met with limited success. The recent trend for climate and hazard plans to incorporate economic and social sectors is stronger in some countries than the reverse. If this continues, the incentives for fisheries and aquaculture authorities to develop and implement their own policies and plans will be further reduced. This may constrain EAF / EAA. For this reason we organize the following information around the sub-components of fisheries and aquaculture, thus encouraging consideration of how changes and hazards interact with each other and within aquatic systems.

In the consultations held in Grenada, Guyana, Jamaica and Belize (see Annex) the matrix shown below was used to encourage and organize discussion (Figure 4.4). Marine capture fisheries were sub-divided into reef (mainly inshore[73]), pelagic (mainly offshore) and continental shelf ecosystems (as in the CLME project) where feasible. Postharvest and supporting services and socio-economic matters were overarching and less dependent on ecosystem, or whether fisheries or aquaculture was discussed.

Climate change disaster hazard	CAPTURE FISHERIES		AQUACULTURE	
	Marine and their support services	Inland and their support services	Coastal and marine	Brackish and freshwater
High temp, drought				
Intense rainfall				
Flooding				
Landslide	We would like to get your views on:			
Storms and hurricanes	1. Vulnerability to changes and hazards			
Sea level rise	2. Capacity gaps/issues to be addressed			
Ocean acidification	3. Proposals for priority strategic action			
Volcano				
Earthquake				
Tsunami				

Figure 4.4 Matrix used for organising discussion during country consultations

[73] Inshore, nearshore and coastal are used all used to refer to the area from the coast to a point offshore which will differ from one country to another depending , for example on the extent and depth of reef or shelf.

The changes and hazards (in the left column) were those most prominent in the literature, especially where countries had assessed vulnerability. They are not in any particular order. “High temperature” was taken as applicable to both air and sea. It was noted that some types of pollution, alien invasive species, diseases and numerous other threats, indirectly linked to or exacerbated by or not necessarily connected to climate and natural hazards, also threaten these productive sectors. Technological hazards such as oil and agrochemicals were beyond the scope of the assessment, but participants in the consultations (particularly from disaster organisations in Belize) provided strong evidence from experience as to why these need to be included, especially in association with flooding and threats to public health.

4.1 Exposure, sensitivity and impacts

Documentation on climate and hazard exposure, sensitivity and impacts on fisheries and aquaculture in the region is scattered and scarce. Typically, data on hydro-meteorological and other disasters are presented as statistics in vulnerability and damage assessments many of which are available online[74]. This abundant information, not specific to fisheries and aquaculture, includes analyses of risks by country[75], economic analyses[76], the cost of taking no action[77], biodiversity perspectives[78] and others.

No analyses were found that used the frameworks described earlier. Some reports either omit fisheries and aquaculture or include them within aggregate information on the agriculture sector. Data at community, household or enterprise levels that could be useful for livelihood analyses may exist in grey literature, or in raw form in various offices. Coming close to this, however, are the historical hazard impact and coping summaries found in some community disaster management plans. An example is the Rocky Point Community Disaster Risk Management Plan that details community re-building cooperation in the aftermath of hurricanes Ivan (2004) and Dean (2007) (ODPEM 2011).

Most assessments related to fisheries and aquaculture concern hurricanes and storms. Below are examples of impact information in which one can see how marine fisheries and inland aquaculture are affected both in monetary terms and in loss of capital assets. The assessments are not based upon livelihood analyses and so do not include many of the factors that could be of interest in promoting community-based adaptation to “build back better”. Jamaica was selected because losses in capture fisheries and aquaculture can be seen for the same event such as Hurricane Dean and then Tropical Storm Gustav (Table 4.1)

[74] E.g. http://www.preventionweb.net; http://www.mona.uwi.edu/cardin/
[75] CARIBSAVE Risk Atlas, Prevention Web, etc.
[76] ECLAC. 2011. The Economics of Climate Change in the Caribbean. Port-of-Spain: The Economic Commission for Latin America and the Caribbean
[77] Bueno, R., C. Herzfeld, E. A. Stanton and, F. Ackerman. 2008. The Caribbean and Climate Change: The Costs of Inaction. Massachusetts, USA: Stockholm Environment Institute-US Center, Global Development and Environment Institute, Tufts University.
[78] Cambers. C., R. Claro, R. Juman, and S. Scott. 2008. Climate change impacts on coastal and marine biodiversity in the insular Caribbean: Report of Working Group II, Climate Change and Biodiversity in the Insular Caribbean. CANARI Technical Report No.382: 87pp

Table 4.1 Summary of damage to the fisheries and aquaculture sectors in Jamaica caused by Hurricane Dean and tropical Storm Gustav, with values in Jamaican dollars
(Source: PIOJ 2007 and 2008)

Hurricane Dean		Tropical Storm Gustav	
Capture fisheries		Capture fisheries	
Fishers directly impacted Value of gear damaged (boats, engines, gear, etc.) Infrastructure damaged (access roads, beach, etc.) Fish habitat damaged (mangroves, reef shoals)	3,500 J$250 mil Much, not quantified Much, not quantified	Fish traps lost (5 parishes) Gear sheds, traps destroyed Shore erosion Larceny	2,185 J$9.5 mil No data No data
Aquaculture		Aquaculture	
Growers directly impacted Value of damage to farms (ornamentals, shrimp, etc.) Infrastructure damaged (ponds, buildings, roads)	23 J$60 mil Much, not quantified	Food fish lost (3 areas) Fingerlings lost (2 areas) Growers reporting losses Total value of infrastructure and fish farm damages	550,000 660,000 34 J$68 mil

The severity of the impacts described above relate to exposure and sensitivity as set out earlier in the vulnerability evaluation model. Following some general observations, we address the relationships between changes and hazards and their actual or potential impacts on fisheries and aquaculture in the CARICOM region. It is not useful to generalise across the 17 states in this assessment due to the considerable differences in their exposure and sensitivity, and we point out some of the reasons.

4.1.1 General observations

Major physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture, incorporating hydro-meteorological disasters, at a global level are set out in an Annex. The box below provides some important key messages for capture fisheries.

Key climate change messages on potential impacts, adaptation, mitigation in capture fisheries

1. Food security in fishing communities will be affected by climate change through multiple channels, including movement of people to coasts, impacts on coastal infrastructure and living space and through more readily observed biophysical pathways of altered fisheries productivity and availability. Indirect changes and trends may interact with, amplify or even overwhelm biophysical impacts on fish ecology.
2. Non-climate issues and trends, for example changes in markets, demographics, overexploitation and governance regimes continue to have a greater effect on fisheries in the short term than climate change.
3. The capacity to adapt to climate change is unevenly distributed across and within fishing communities. It is determined partly by material resources but also by social/household structures, networks, technologies and appropriate governance structures. Patterns of vulnerability of fisher folk to climate change are determined both by this capacity to adapt to change and by the observed and future changes to ecosystems and fisheries productivity.
4. Building adaptive capacity can reduce vulnerability to a wide variety of impacts, many of them unpredictable or unforeseen. The key role for government intervention is to facilitate adaptive capacity within vulnerable communities.
5. There is a wide range of potential adaptation options for fisheries, but considerable constraints on their implementation for the actors involved, even where the benefits are significant. For

government interventions there may be trade-offs between efficiency, targeting the most vulnerable and building resilience of the system.

Source: Adapted from Daw et al (2009)

Some details are provided for easy reference below taking note of both direct and indirect pathways (Table 4.2).

Table 4.2 Potential impacts of climate change on fisheries, global overview (Source: Daw et al 2009)

Type of Changes	Physical changes	Processes	Potential impacts on fisheries
Physical environment (indirect ecological)	Increased CO_2 and ocean acidification	Effects on calciferous animals e.g. molluscs, crustaceans, corals, echinoderms and some phytoplankton	*Potentially **reduced production** for calciferous marine resources and ecologically related species and **declines in yields***
	Warming upper layers of the ocean	Warm-water species replacing cold-water species	***Shifts in distribution** of plankton, invertebrates, fishes and birds towards the North or South poles, reduced species diversity in tropical waters*
		Plankton species moving to higher latitudes	
		Timing of phytoplankton blooms changing Changing zooplankton composition	*Potential mismatch between prey (plankton) and predator (fish populations) and **reduced production and biodiversity** and **increased variability in yield***
	Sea level rise	Loss of coastal fish breeding and nursery habitats e.g. mangroves, coral reefs	***Reduced production and yield** of coastal and related fisheries*
Fish stocks (indirect ecological)	Higher water temperatures	Changes in sex ratio Altered time of spawning Altered time of migrations Altered time of peak abundance	*Altered timing and **reduced productivity** across marine and fresh water systems*
	Changes in ocean currents	Increased invasive species, diseases and algal blooms	***Reduced productivity** of target species in marine and fresh water systems*
		Changes in fish recruitment success	*Abundance of juvenile fish affected leading to **reduced productivity** in marine and fresh water*
Ecosystems (indirect	Reduced water flows and increased droughts	Changes in lake water levels Changes in dry water flows in rivers	***Reduced productivity** of lake fisheries* ***Reduced productivity** of river fisheries*

Type of Changes	Physical changes	Processes	Potential impacts on fisheries
ecological)	Increased frequency of ENSO events	Changes in timing and latitude of upwelling	***Changes in distribution*** *of pelagic fisheries*
		Coral bleaching and die-off	***Reduced productivity*** *coral-reef fisheries*
Disturbance of coastal infrastructure and fishing operations (direct)	Sea level rise	Coastal profile changes, loss of harbours, homes.	***Increased vulnerability*** *of coastal communities and infrastructure to storm surges and sea level*
		Increased exposure of coastal areas to storm damage	*Costs of adaptation lead to* ***reduced profitability****, risk of storm damage* ***increases costs*** *of insurance and/or rebuilding*
	Increased frequency of storms	More days at sea lost to bad weather, risks of accidents increased	***Increased risks*** *associated with fishing, making it less viable livelihood options for the poor*
		Aquaculture installations (coastal ponds, sea cages) more likely to be damaged or destroyed	***Reduced profitability*** *of larger-scale enterprises, insurance premiums rise*
Inland fishing operations and livelihoods (indirect socio-economic)	Changing levels of precipitation	Where rainfall decreases, reduced opportunities for farming, fishing and aquaculture as part of rural livelihood systems	***Reduced diversity of rural livelihoods****; greater risks in agriculture; greater reliance on non-farm income.* ***Displacement of populations*** *into coastal areas leading to influx of new fishers*
	More droughts or floods	Damage to productive assets (fish ponds, weirs, rice fields, etc.) and homes	***Increasing vulnerability*** *of riparian and floodplain households and communities*
	Less predictable rain/dry seasons	Decreased ability to plan livelihood activities – e.g. farming and fishing seasonality	

Several publications set out what can be expected and what is uncertain for the Caribbean region[79]. We briefly highlight some of the main concerns for various systems. Specifics will vary considerably across the 17 CRFM members and situations change constantly. See further reading for more detail.

4.1.2 Marine fisheries

In the case of Caribbean marine fisheries the differences in exposure, sensitivity and potential impact by type of ecosystem and location can be quite significant. These differences depend, however, in part on the extent to which one takes into account the indirect pathways and longer term variables and cycles described earlier. For example, rainfall or flooding that immediately impacts the coast may also have impacts offshore on pelagic and shelf systems in a matter of days to weeks. Within that time and space the impacts would be mediated by food webs and bio-physical oceanographic processes. Some examples are below (Table 4.3).

[79] E.g. Mahon (2002), Cambers et al (2008), Day (2009), Nurse (2011)

Table 4.3 Examples of hazards, exposure, sensitivity and potential impacts for marine fisheries

Hazard	Exposure and Sensitivity	Examples of potential impacts
High temp, drought	Highest direct impact on coastal fisheries. Coral reefs are very sensitive.	• Reef impacts such as coral bleaching, fish kills • Increased storm and hurricane formation, intensity • Alteration of mangrove and estuarine fish life cycles
Intense rainfall	Highest direct impact on coastal fisheries. Coral reefs are very sensitive.	• Reef impacts such as sedimentation, seabed scouring • Physical damage due to flow, debris transportation • Infrastructure damage due to poor drainage planning
Flooding	Highest direct impact on coastal fisheries. Coral reefs are very sensitive.	• Reef impacts such as salinity changes, turbidity • Freshwater lenses may increase offshore productivity • Freshwater lenses may transport pathogens (fish kill)
Landslide	Highest direct impact on coastal fisheries. Coral reefs are very sensitive.	• Reef impacts such as smothering, increased turbidity • Physical damage to wetlands, altered circulation • Damage to fishing community infrastructure, roads
Storms and hurricanes	Highest direct impact on coastal fisheries. Coral reefs are very sensitive.	• Physical damage due to wave action, debris transport • Coastal residences and other infrastructure damage • Loss of life and property at sea, particularly offshore
Sea level rise	Highest direct impact on coastal fisheries. Coral reefs are very sensitive.	• Changes in nature and distribution of nursery habitat • Inundation of coastal infrastructure e.g. fish markets • Reduced space for vessel haul-out for maintenance
Ocean acidification	Highest direct impact on coastal fisheries. Coral reefs are very sensitive.	• Reef impacts such as weakened coral structure • Unpredictable changes in plankton composition • Calcification impaired in several marine species
Volcano	Can impact offshore and inshore fisheries	• Damage to fisheries communities and infrastructure • Changed landscapes and seascapes as in Montserrat • Reduced density imperils vessels (Kick 'em Jenny)
Earthquake	More likely to impact coastal fisheries	• Changed landscapes and seascapes as in Port Royal • Disruption of entire fishing communities as in Haiti
Tsunami	More likely to impact coastal fisheries	• Loss of life and property at sea, offshore and inshore • Physical alteration to coasts and inland areas affected

According to Nurse, "while there is a need for considerably more research especially at the species level, there already exists a good generic understanding of the potential impacts of climate change and climate variability on key factors and processes that influence recruitment, abundance, migration, and the spatial and temporal distribution of many fish stocks"[80]. This involves applying information on other geographic regions to the Caribbean, to the extent possible. See the general information on physical and ecological impacts in Annex 7.3 for example. Below are some additional points and lessons from literature on climate and disaster impacts in the Caribbean. Adaptive capacity and resilience are addressed later.

- Minimal attention to the Code of Conduct for Responsible Fisheries (CCRF) and other relevant international and regional policy guidance in most countries hinders adaptation
- Since EAF, ICM and EEZ management are not widely practiced, the interactions among sectors and among habitats are problematic in mainstreaming CCA and DRM
- Benefits of applying good governance and co-management principles have been widely discussed but there are few success stories due to inconsistent application and engagement

[80] (Nurse 2009:131), but also see Mahon (2002), Cambers et al (2008), ECLAC (2011) etc. for similar points

- Since CCA and DRM are not mainstreamed, the notion that the key contributor to building adaptive capacity and resilience is good fisheries management has not been institutionalised
- El Niño Southern Oscillation (ENSO) events (climate variability) are strong environmental drivers for fisheries-related patterns in the Caribbean, but relationships are poorly understood
- Links between ENSO events, changes in fish abundance and availability, fish landings and prices, harvest and postharvest livelihoods and food security can be constructed
- There are no mechanisms for including climate data in fisheries assessments or fisheries-relevant data in climate models although the institutional potential for doing so exists
- Higher intensity rough sea events and more rapid onset, reduce the windows of opportunity for early warning systems that allow enterprises and communities to prepare or evacuate
- Links between high SST and harmful algal blooms were reported in the Belize consultations
- Ocean acidification is a new hazard, the potential impacts of which are extremely uncertain
- Most small-scale fishing enterprises (e.g. boats, gear, lockers) are not insured, and often no insurance is available or affordable, resulting in high risk and individual or public expenses
- There are few guidelines or incentives to "build back better" such as increasing the minimum mesh size in fish traps when recovery efforts supply wire mesh to affected fishers
- Very long lag phases between agreement that legislative amendment is required and making the necessary changes severely constrain legal-institutional and policy adaptive capacity
- MPAs remain more aimed at general biodiversity conservation or earning tourism revenues rather than treated as fisheries management tools, thus limiting their full adaptation potential
- Limited regional capacity for physical, chemical and biological oceanography constrains the use of oceanographic data for use in fisheries and climate models, despite some monitoring
- Market acceptance of new species of marine fish is likely to vary culturally and with location
- Potential impacts of climate and disasters on recreational fisheries are less well documented than for commercial fisheries but are likely to share many of the same attributes
- Sea defences have altered commercial fishing such as in Grenada where in some places seining is no longer possible from the beach, so fishers have adapted to seine nearshore
- Coastal defence structures such as groynes and revetments seem to be providing new habitat especially for juvenile finfish and shellfish but impacts on fisheries are not documented
- Impacts on reefs and associated ecosystems (mangroves and seagrass) may depend mainly on the interactions amongst natural and technological hazards rather than any one driver
- Impacts on fish stock distribution, spawning, recruitment, total biomass etc. are not likely to be much better researched in the future if research costs and data sharing are problematic
- Disturbances to habitat due to rough sea events and storm surge may allow some species to be more catchable whereas other species will become less available, and fishing more dangerous
- Countries that depend mainly on inshore and reef resources may be the most vulnerable
- Impacts vary with vessel size such as if small vessels fish less days due to rough seas but large vessels are more at risk of damage by being more difficult to secure in safe harbour
- Postharvest revenue will vary in different directions and to different extents due to changes in the type and amount and timing of landings as well as the vulnerability of the infrastructure
- Both fixed and operational costs in the harvest sector are likely to increase from direct and indirect pathways involving insurance, vessel gear and equipment, fuel, ice etc.
- Declining national revenue (e.g. GDP) from fisheries due to changes and disasters may prompt less rather than more allocation of funds from the national budget for fisheries
- Impacts upon fishing communities may make fishing less viable as a livelihood in terms of household decisions on risk spreading, but also in terms of practicality (e.g. if re-located)

- Even if resources are abundant and available, fishing from cays and low-lying islands far from safe harbour will become increasingly dangerous and an issue of social vulnerability

4.1.3 Inland fisheries

Inland fisheries are of much less commercial importance in CRFM countries, featuring mainly in the largest and wettest (e.g. Guyana and Suriname) apart from low-level subsistence fishing found almost everywhere. The climate and disaster features of these fisheries are shown below (Table 4.4).

Table 4.4 Examples of hazards, exposure, sensitivity and potential impacts for inland fisheries

Hazard	Exposure and Sensitivity	Examples of potential impacts
High temp, drought	Highest direct impact on shallowest water areas, seasonal water bodies.	• Reduced productivity as tolerances are exceeded • Likely shrinkage of fishable area, increased conflicts • Alteration of livelihoods if combined with agriculture
Intense rainfall	Sensitive in poorly managed areas and eroding watersheds.	• Impacts such as sedimentation, riverbed scouring • Physical damage due to flow, debris transportation • Infrastructure damage due to poor drainage planning
Flooding	Highest direct impact on shallowest water areas, seasonal water bodies.	• Possible higher productivity in newly flooded areas • Habitat flooding may increase some spawning areas • Possible public health hazard due to agrochemicals
Landslide	Sensitive in poorly managed areas and eroding watersheds.	• Physical watercourse blockage and altered drainage • Damage to fishing community infrastructure, roads • Destruction of critical habitat reduces productivity
Storms and hurricanes	Little exposure unless an extensive landfall or via indirect pathways.	• Physical damage due to waves, wind if near the coast • May be accompanied by intense rainfall, flooding
Sea level rise	Little exposure except in coastal floodplain prone to marine inundation.	• Exacerbation of coastal infrastructure impact by flood • Saline intrusion may completely alter habitats inland
Ocean acidification	No to low and uncertain.	• Unlikely to have impact
Volcano	Impact may be highest on steep slopes but ash can impact large areas	• Physical damage to fisheries and public infrastructure • Changed landscapes, water flows and habitats • Altered chemical composition of water bodies
Earthquake	Rare occurrence but perhaps high sensitivity	• Changed landscapes, water flows and habitats • Damage to communities and public infrastructure
Tsunami	Unlikely to impact much except coastal plains	• Physical alteration to inland areas adjacent to coasts

In addition to the general information on impacts provided above and in the annex, we offer some additional points and lessons from literature on climate and disaster impacts in the Caribbean. Adaptive capacity and resilience are addressed later.

- Disaster statistics on the impacts experienced by inland fisheries are scare and may need to be addressed primarily by local knowledge through oral histories rather than in scientific studies
- Few countries have fisheries policies and plans that address inland fisheries (e.g. Guyana is now in the process of doing so for its hinterland/interior fisheries), so new opportunities exist for mainstreaming CCA and DRM

- Inland fisheries management incorporating CCA and DRM may need to consider land tenure, rights and traditions of indigenous people and concerns not applicable to marine fisheries
- In relatively large countries (e.g. Guyana, Suriname) inland fishing may be far removed from the fisheries management authority, making community-based management essential
- Threats to inland fishing from watershed activities such as forestry, agriculture and mining interact considerably with natural disasters and feature in sustainable land use management
- Depending upon the interactions among hazards and changes some opportunities may be presented compared to a much more negative outlook in the marine fisheries sector

4.1.4 Aquaculture in general

A FAO Workshop gathering experts who prepared the Regional Aquaculture Review for Latin America and the Caribbean recently addressed this topic[81]. Some common issues identified by the experts included:

- Lack of estimation of economic and social impacts of aquaculture as well as the scarcity of information about the impact on local protein consumption
- Weak coordination and management of environmental issues particularly regarding institutional coordination (usually among fisheries and environmental institutions)
- Need for strengthening of government and institutional frameworks
- Need for enhancing of sub-regional and regional cooperation
- Need to control the spread of diseases, and particularly regarding movements of exotic species

Aquaculture does not usually extend as far seaward as marine fisheries but it may cover the same areas as inland fisheries. In many places it is concentrated along coasts whether marine, brackish water or freshwater[82]. Although aquaculture can be quite vulnerable to hazards, some changes in climate may prove to be beneficial to some types of well-managed production. Potential impacts are shown below (Table 4.5).

Table 4.5 Potential impacts of climate change on aquaculture (Source: Barange and Perry 2009)

Drivers of change	Impacts on culture systems	Operational impacts
Sea surface temperature changes	Increase in harmful algal blooms Decreased dissolved oxygen Increased disease and parasites Longer growing seasons Changes in locations and ranges of suitable species Reduced winter natural mortality Enhanced growth and food conversion rates	Changes in infrastructure and operation costs Increased fouling, pests, nuisance species and predators Expanded geographic ranges for species Changes in production levels

[81] Morales Q. and R. Morales. 2006. Regional review on aquaculture development. Latin America and the Caribbean – 2005. FAO Fisheries Circular. No. 1017/1. Rome, FAO. 177 pp.

[82] Hernández-Rodríguez, A., Alceste-Oliviero, C., Sanchez, R., Jory, D., Vidal, L. & Constain-Franco, L.-F. 2001. Aquaculture development trends in Latin America and the Caribbean. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 317-340. NACA, Bangkok and FAO, Rome.

Drivers of change	Impacts on culture systems	Operational impacts
	Competition, parasitism and predation from altered local ecosystems, competitors, and exotic species	
Changes in other oceanographic variables	Decreased flushing rates and food availability to shellfish Changes in abundance of species used for food and fishmeal	Accumulation of wastes under nets Increased operating costs
Sea level rise	Loss of areas for aquaculture Loss of areas providing physical protection Greater flooding risks Salt intrusions into groundwater	Infrastructure damage Change in aquaculture zoning Increased insurance costs Reduced freshwater availability
Increased storm activity	Larger waves Higher storm surges Flooding from precipitation Salinity changes Structure damage	Loss of stock Facility damage Higher costs for designing new facilities Increased insurance costs
Drought and water stress	Salinity changes Reduced water quality Increased diseases Uncertain water supplies	Loss of stock Facility damage Conflicts with outer water users Reduced production capacity Change in cultured species

4.1.5 Marine aquaculture

Marine aquaculture is not yet well developed in Caribbean countries. Some considerations are shown below (Table 4.6).

Table 4.6 Examples of hazards, exposure, sensitivity and potential impacts for marine aquaculture

Hazard	Exposure and Sensitivity	Examples of potential impacts
High temp, drought	Highest direct impact on inshore aquaculture.	• Reduced oxygenation and increased salinity • Increased growth of cultured and nuisance species
Intense rainfall	Highest direct impact on inshore aquaculture.	• Runoff impacts such as sedimentation, nutrients • Infrastructure damage due to poor drainage planning
Flooding	Highest direct impact on inshore aquaculture.	• Lower salinity, possible agrochemical hazards • Freshwater may introduce new pathogens to bivalves
Landslide	Minimal unless indirect	• Damage to coastal community infrastructure, roads
Storms and hurricanes	Highest direct impact on inshore aquaculture.	• Physical damage due to wave action, debris transport • Coastal community and other infrastructure damage • Additional cost of early warning and safety measures
Sea level rise	Highest direct impact on inshore aquaculture.	• Changes in areas available either positive or negative • Inundation of supporting coastal infrastructure
Ocean acidification	Highest direct impact on inshore aquaculture.	• Unpredictable changes in plankton composition • Calcification impaired in several marine species
Volcano	Minimal unless indirect	• Damage to coastal community infrastructure, roads
Earthquake	Minimal unless indirect	• Damage to coastal community infrastructure, roads

Hazard	Exposure and Sensitivity	Examples of potential impacts
Tsunami	Highest direct impact on inshore aquaculture.	• Loss of life and property at sea, offshore and inshore • Physical alteration to coasts and inland areas affected

In addition to the general information on impacts provided above and in the table, we offer some additional points and lessons from literature on climate and disaster impacts in the Caribbean. Adaptive capacity and resilience are addressed later.

- There is little existing small-scale marine aquaculture in the CARICOM region apart from seamoss cultivation, so the impacts on existing enterprises are going to be small overall
- The scenarios for marine fisheries that predict increasing hazards, especially from storms and hurricanes, are likely to constrain mariculture development
- Mariculture in nearshore areas will be increasingly threatened from both the land and the sea
- While changes such as higher sea surface temperatures may increase growth rates of cultured organisms they may also accelerate growth of fouling and disease organisms as well
- Shifts in ocean regimes may make it possible to culture new species, but are more likely to make no difference or to reduce the number of cultured species due to ocean warming
- Since many women are involved in coastal seamoss culture and processing of value-added goods they may be more vulnerable to the impacts of climate and disasters than men

4.1.6 Freshwater and brackish water aquaculture

Freshwater and brackish water aquaculture are becoming better developed in some of the larger countries and very small-scale, often integrated, operations can be found in most of the countries. The considerations vary especially with the size (spatially) and type (intensity) of the operation (Table 4.7).

Table 4.7 Examples of hazards, exposure, sensitivity and potential impacts for fresh and brackish water aquaculture

Hazard	Exposure and Sensitivity	Examples of potential impacts
High temp, drought	Highest direct impact on shallowest water areas	• Reduced productivity if tolerances are exceeded • Possible higher growth rates of some species
Intense rainfall	Highest direct impact on poorly drained areas	Erosion of natural earth ponds and dykes Physical damage due to redirected flow and debris Infrastructure damage due to inadequate drainage
Flooding	Highest direct impact on low lying areas.	• Impacts such as pond overtopping, escape of species • Possible public health hazard due to agrochemicals
Landslide	Poorly managed areas, rivers and watersheds.	• Physical watercourse blockage and altered drainage • Damage to rural community infrastructure, roads
Storms and hurricanes	Little exposure unless an extensive landfall.	• May be accompanied by intense rainfall, flooding
Sea level rise	Little exposure except in coastal floodplain.	• Exacerbation of impact on infrastructure due to flood • Saline intrusion may completely alter feasibility
Ocean acidification	No to low and uncertain.	• Unlikely to have impact
Volcano	Impact may be highest on steep slopes, sources	• Changed landscapes, water flows and habitats • Altered chemical composition of water bodies
Earthquake	Rare occurrence but perhaps high sensitivity	• Changed landscapes, water flows and habitats • Damage to communities and public infrastructure

Hazard	Exposure and Sensitivity	Examples of potential impacts
Tsunami	Unlikely to impact much except coastal plains	• Physical alteration to inland areas adjacent to coasts

In addition to the general information on impacts provided above and in the table, we offer some additional points and lessons from literature on climate and disaster impacts in the Caribbean. Adaptive capacity and resilience are addressed later.

- Few countries have fisheries policies and plans that address freshwater aquaculture (e.g. Guyana is now in the process), so opportunities exist for mainstreaming CCA and DRM
- Freshwater and brackish water aquaculture incorporating CCA and DRM needs to consider land tenure, indigenous people and other aspects of sustainable land use management
- In relatively large countries (e.g. Guyana, Suriname) inland aquaculture is generally small-scale and, being widespread, it is difficult for any central aquaculture authority to manage , making community-based area management essential
- Threats to inland aquaculture from other watershed activities such as forestry, agriculture and mining may interact with natural disasters
- Depending upon the interactions among hazards and changes some opportunities may be presented compared to a much more negative outlook in marine areas
- Sea level rise and coastal inundation are likely to favour the development of brackish water aquaculture in areas that have had to be abandoned by agriculture, presenting opportunities
- Highly tolerant species such as tilapia have been introduced in countries such as Haiti as a major contributor to post-disaster recovery and improving food security at community level

4.2 Adaptive capacity and reducing vulnerability

The assessment of exposure, sensitivity and potential impacts prompts us to ask what interested parties and stakeholders in CRFM countries have done to develop adaptive capacity, reduce vulnerability and build resilience at regional, national and local levels. Earlier we mentioned several large projects and there are hundreds more in the CCCCC database. However, few are aimed mainly at fisheries and aquaculture. This section does not attempt to catalogue these initiatives, but selects examples of issues and actions that will help to inform the strategic action plan and programme. We draw heavily upon the comments and recommendations received during the consultations in Grenada, Guyana, Jamaica and Belize. These are often not tied to specific resource systems or hazards. Limited human and other resources prompt SIDS to tackle aquatic system hazards with similar measures where feasible. Participants in the consultations made it clear that partitioning and compartmentalising the analysis by hazard or type of production system was of limited practical value since institutions and organisations typically had to deal with multiple economic sectors and multiple hazards together.

Social-ecological systems such as fisheries and aquaculture may demonstrate the ability to adapt to changes caused by a variety of drivers. However, the rate at which climatic change occurs, the amplitude of climate variability, and the frequency and severity of hazard impacts may combine to exceed the rate at which SES can adapt. Natural environments that are already stressed by human activities have reduced ability to cope with (short term) and to adapt to (longer term) climate change. When social systems are focused on coping strategies rather than adaptation, such as in poverty, the options to adapt may be compromised by such strategies, thereby creating a very wicked problem.

Before providing some Caribbean perspectives, general information on adaptation in fisheries and aquaculture is shown in Table 4.8 and Table 4.9 respectively.

Table 4.8 Adaptation to climate impacts in fisheries, global overview (Source Daw et al 2009)

Impact on fisheries	Potential adaptation measures	Responsibility	Timescale
Reduced fisheries productivity and yields (indirect ecological)	Access higher value markets	Public / Private	Either
	Increase effort or fishing power*	Private	Either
Increased variability of yield (indirect ecological)	Diversify livelihood portfolio Insurance schemes	Private Public	Either Anticipatory
	Precautionary management for resilient ecosystems	Public	Anticipatory
	Implementation of integrated and adaptive management	Public	Anticipatory
Change in distribution of fisheries (indirect ecological)	Private research and development and investments in technologies to predict migration routes and availability of commercial fish stocks*	Private	Anticipatory
	Migration*	Private	Either
Reduced profitability (indirect ecological and socio-economic)	Reduce costs to increase efficiency	Private	Either
	Diversify livelihoods	Private	Either
	Exit the fishery for other livelihoods/investments	Private	Reactive
Increased vulnerability of coastal, riparian and floodplain communities and infrastructure to flooding, sea level and surges (direct)	Hard defences*	Public	Anticipatory
	Managed retreat/ accommodation	Public	Anticipatory
	Rehabilitation and disaster response	Public	Reactive
	Integrated coastal management	Public	Anticipatory
	Infrastructure provision (*e.g.* protecting harbours and landing sites)	Public	Anticipatory
	Early warning systems and education	Public	Anticipatory
	Post-disaster recovery	Public	Reactive
	Assisted migration	Public	Reactive
Increased risks associated with fishing (direct)	Private insurance of capital equipment	Private	Anticipatory
	Adjustments in insurance markets	Private	Reactive
	Insurance underwriting	Public	Reactive
	Weather warning system	Public	Anticipatory
	Investment in improved vessel stability / safety	Private	Anticipatory
	Compensation for impacts	Public	Reactive
Trade and market shocks (indirect socio-economic)	Diversification of markets and products	Private / public	Either
	Information services for anticipation of price and market shocks	Public	Anticipatory

Impact on fisheries	Potential adaptation measures	Responsibility	Timescale
Displacement of population leading to influx of new fishers (indirect socio-economic)	Support for existing local management institutions	Public	Either
Various	Publicly available research and development	Public	Anticipatory

Table 4.9 Adaptation to climate impacts on aquaculture, global overview (Source: De Silva and Soto 2009)

Aq. / Other Activity	Impact (s)		Adaptive Measures
	+/-	Type form	
All: cage, pond; fin fish	-	Raise above optimal range of tolerance	Better feeds; selective breeding for higher temperature tolerance
FW; all	+	Increase in growth; higher production	Increase feed input
FW: cage	-	Eutrophication & upwelling; mortality of stock	Better planning; sitting, conform to cc, regulate monitoring
M/FW; mollusc	-	Increase virulence of dormant pathogens	None; monitoring to prevent health risks
Carnivorous fin fish/ shrimp*	-	Limitations on fishmeal & fish oil supplies/price	Fishmeal & fish oil replacement; new forms of feed management; shift to non- carnivorous commodities
Artificial propagation of species for the “luxurious” LFRT*	(+)	Coral reef destruction	None; but aquaculture will impact positively by reducing an external driver contributing to destruction and help conserve biodiversity
Sea level rise and other circulation changes			
All; primarily in deltaic regions	+/-	Salt water intrusion	Shift upstream stenohaline species- costly; new euryhaline species in old facilities
	+/-	Loss of agricultural land	Provide alternative livelihoods- aquaculture: capacity building and infrastructure
Marine carnivorous fin fish*	-/+	Reduced catches from artisanal coastal fisheries; loss of income to fishers	Reduced feed supply; but encourages use of pellet feeds- higher cost / environmentally less degrading
Shell fish	-	Increase of harmful algal blooms- HABs	Mortality and increased human health risks by eating

Aq. / Other Activity	Impact (s)		Adaptive Measures
			cultured molluscs
Habitat changes/loss	-	Indirect influence on estuarine aquaculture; some seed availability	None
Acidification			
Mollusc / seaweed culture	-	Impact on calcareous shell formation / deposition	None
Water stress (+ drought conditions etc.)			
Pond culture	-	Limitations for abstraction	Improve efficacy of water usage; encourage non-consumptive water use aquaculture, e.g. CBF
Culture-based fisheries	-	Water retention period reduced	Use of fast growing fish species; increase efficacy of water sharing with primary users e.g. irrigation of rice paddy
Riverine cage culture	-	Availability of wild seed stocks reduced / period changed	Shift to artificially propagated seed; extra cost
Extreme climatic events			
All forms; predominantly coastal areas	-	Destruction of facilities; loss of stock; loss of business; mass scale escapement with the potential to impacts on biodiversity	Encourage uptake of individual / cluster insurance; improve design to minimize mass escapement; encourage use of indigenous species to minimize impacts on biodiversity

Temp.- temperate; Tr.- tropical; STr.- Sub- tropical; LFRT- live fish restaurant trade; CBF- Culture based fisheries.
* instances where more than one climatic change element will be responsible for the change.

4.2.1 Driven by fisheries / aquaculture or CCA / DRM

The Mainstreaming Climate Change in Disaster Management (CCDM) project aims to enhance the resilience in CDEMA Participating States to respond to the effects of climate change and natural disasters through practical planning and adaptation interventions at the national and community levels. It gives an example of how the fisheries sector could be integrating CCA and DRM (Table 4.10). The three pillars address multi-level governance and safety at sea (aspect of livelihoods).

Table 4.10 Example of fisheries integration of CCA and DRM (Source: CDEMA 2010)

Fisheries sector	Desired results
	1. Enhanced fisheries policy development and execution which incorporates CC and DRR. (Note: The CLME Project provides an opportunity for reaching all levels – CLME model uses a multi-layered policy cycle with focus on governance) 2. Enhanced Fisheries Management Plans (FMPs) which incorporate DRR and CC and re implemented. (Note: Use opportunity of the ACP Fish II Project – Policy and fisheries management component) 3. Fishers using safer vessels

In the country consultations, however, the climate and disaster authorities, NGOs and community participants were largely unaware of the CLME Project and its potential to fulfil this function. A few countries are indeed using the ACP Fish II Project to address deficiencies in fisheries policy and planning documentation including incorporating CCA and DRM. Yet it appears from draft documents not yet in the public domain that the depth of treatment differs considerably, and in two out of three cases examined their inclusion is only in general principles[83]. Some countries such as Barbados have draft legislation on vessel safety and training in safety at sea is conducted, but the links to CCA and DRM are tenuous. There was considerable debate in the Jamaica consultations on what would be safe and affordable vessels for even more adaptive and responsible approaches to fishing further offshore.

If CCA and DRM initiatives continue to set the tone and pace for fisheries and aquaculture it is likely that the decision-making locus and power on climate and disaster issues related to these sectors will shift from the fisheries and aquaculture authorities to the climate and disaster offices. It may not be that the latter offices seek this responsibility and authority, but the institutional arrangements may so dictate unless there is a turnaround in current trends. The most significant evidence of such a move would be the formulation and implementation of fisheries management plans that incorporated CCA and DRM throughout, and especially down to the detailed fishery or region level as experts advocate.

The slow but increasing trend across the region towards EBM/EAF and ICM, as reflected in the key documents in this assessment and especially the CCCFP, is encouraging for adaptation and resilience but may be too little too late unless the pace accelerates. The CLME project is but one vehicle for this.

4.2.2 Geological hazards

Geologic events include earthquakes, tsunamis and volcanoes which in turn produce several types of hazards such as ground shaking and landslides, land and seabed faulting, coastal inundation and subsidence, lava flows, hot gases and ash, and more. The UWI Seismic Research Centre monitors seismic activity through a network of seismographs for early warnings that generate information for disaster decision-making. These are not hydro-meteorological events associated with climate change but they also may result in disasters and the latter may have increased impact due to sea level rise or other climate effects on coasts especially.

The volcanism of Montserrat is well known as well as the lower level of volcanic activity in several of the islands in the eastern Caribbean, including Dominica with its ‘champagne reef’. On 12 January 2010 Haiti suffered a 7.0 magnitude earthquake resulting in a tsunami that affected nearby shores soon afterwards. In the four country consultations most participants, especially from the fishing and aquaculture industries said that realistically there was little they could do to adapt to geologic risks although some types of insurance and early warning may assist in reducing the risks. Their main concern was insufficient warning. CDEMA and partners have developed a Model Tsunami Warning Information Dissemination Protocol, Standard Operating Procedures and much public information material[84]. The Pacific Tsunami Warning Centre (PTWC) provides interim services to the Caribbean which is expected to have its own early warning system in place by 2014.

4.2.3 Increasing interagency collaboration

Several agencies in the country consultations and otherwise have concluded that there is an urgent need to rationalise the many CCA and DRM initiatives across the region, and even nationally in some

[83] Personal communication from Sandra Grant, Regional Manager for the Caribbean, ACP FISH II Programme
[84] http://weready.org/tsunami/

cases, in order to reduce inefficient planning, duplication of effort, wastage of limited resources and fatigue of intended beneficiaries. The latter are becoming overwhelmed at the community level in some locations by frequent workshops and research accompanied by an implementation gap in which little that is tangible is seen to be accomplished. The example of Old Harbour Bay in Jamaica was offered. This is an overarching issue in CCA and DRM, not confined to fisheries and aquaculture. An increased thrust among agencies at all levels to communicate, coordinate and collaborate is required.

Stakeholders, particularly at the community level and from DRM agencies, observed that although CCA and DRM are almost congruent, initiatives concerned with climate change tended treat DRM as a separate issue, thereby exacerbating unnecessary duplication. This was, in part, tied to their funding. They recommended that collaboration be strong and differences minimised at the local level where it was adding to confusion and eroding initiatives to increase public awareness of CCA and DRM.

The CARICOM Task Force on Climate Change and Development could be a forum for the high level coordination and collaboration among stakeholders required to better integrate CCA and DRM as well as bring in fisheries and aquaculture productive sectors through the Caribbean Community Common Fisheries Policy. It appears that this forum is activated primarily for multilateral climate negotiations. The CCCCC IP needs to drill down to the community level and to ensure that all stakeholders are vertically and laterally linked where necessary in a nested and modular network design featuring key hubs for de-centralised and devolved management responsibility.

4.2.4 Climate smart communities

The CSCDM Programme was initiated by the CDEMA Mainstreaming Climate Change into Disaster Risk Management for the Caribbean Region (CCDM) Project (2009 - 2011). Apparently still valid are the main challenges and solutions to implementation listed by CDEMA's Civil Society Sub-Committee in January 2011. To these have been added observations from stakeholder consultations held in the four countries visited (Table 4.11).

Table 4.11 Climate smart community challenges and enabling environment (Adapted from CDEMA 2011c)

Main challenges being faced	Enabling environment required
• Less political incentives to invest in mitigation and adaptation resources compared with visible and popular infrastructural or social programmes • Donors give more generously for humanitarian post-disaster recovery compared to DRM / DRR • National and regional institutional framework for CCA and DRM that is not conducive to collaborative, integrated programmes • Institutional fragmentation results in some aspects of community capacity building being duplicated whilst others are not addressed at all, and there is little peer exchange of experiences or best practices • In most countries, failure to date to integrate community level initiatives into the national framework or to provide information to communities about this framework	• Policy environment that actively promotes integrated CCA / DRM and the opportunities these present for improving livelihoods • Institutional mechanisms facilitate integrated implementation of CSCDM by many actors who share experiences and best practices, and to jointly monitor and evaluate outcomes • Greater international commitment of finance and technical support to the most vulnerable developing countries, including those in the Caribbean, allocated based on actual need • Adequate funding to build the capacities of organisations implementing CSCDM or such programs at the national level and resources to implement programs in communities over a minimum period of three years in any given community (possibly longer depending on the capacity at the outset and the problems • Pooling of funds and networking of change

Main challenges being faced	Enabling environment required
• Increasing but still relatively low community awareness of the likely impacts of climate change and the implications for DRM • Lack of climate change data at appropriate resolution for community-based planning • Difficulty in providing the type of long-term sustained support that is needed to build a community's capacity given a donor funding landscape that promotes short-term projects • Unrealistic expectations of communities on the timescale between planning and results, especially for infrastructure and relocation • "Quarrelling communities" plagued by high levels of internal conflict and low levels of conflict management and local leadership require social science beyond agencies' skills	agents to create the critical masses for change • Invest more in learning-by-doing approaches rather than primarily planning and workshops so results can be included in social learning • Commitment to participatory planning, implementation, monitoring and evaluation of the programs with all key stakeholders, at community and national levels • Incorporate different knowledge types and promote equity and buy-in at all levels • Establishment of knowledge networks and communities of practice accessible by all to provide up-to-date climate change data, share best practices, provide opportunities through social networking for communities to exchange experiences locally and regionally

The previously described DRM benchmarking tool (the B-tool) developed for the OECS is also relevant at the community level, especially in providing guidelines and checklists for ensuring preparedness that are useful at the local level.

4.2.5 Community Disaster Risk Management Plans

Notwithstanding the challenges with creating climate smart communities there has been progress in producing community disaster risk management plans and other related products in the Caribbean via a large number of projects at both regional and national level. Several of these plans are for fishing communities (e.g. Old Harbour Bay and Rocky Point in Jamaica). Communities have put much effort into these products, demonstrating a willingness to participate and fully engage. The plans include community hazard maps, institutional arrangements and adaptation recommendations.

4.2.6 Knowledge mobilisation

In the country consultations, fisheries and aquaculture authorities actively involved in CCA and DRM initiatives were largely unaware of the several sets of information and tools available via internet at their disposal (e.g. the CARIBSAVE Risk Atlases[85] and CDEMA tools for CCA2DRR[86]). Regarding the CCA2DRR products, those who were aware of them noted that most tools needed to be further "translated" or adapted for use in community level activities to ensure socio-cultural fit. They thought this was inevitable, but it used up scarce resources in governmental and civil society agencies. Efficient ways to do this are required.

A broader issue in knowledge mobilisation is that of communication generally. When fishers from across the region gathered a few years ago to discuss their perspectives on climate change amongst themselves, and with marine scientist and managers, there were far more questions than answers[87].

[85] http://www.caribsave.org/ ; see Simpson et al references
[86] www.cdema.org/; see CDEMA references
[87] CERMES. 2009. Report of the Fishers Forum: "Climate change and small-scale fisheries in the Caribbean" at the 61st Gulf and Caribbean Fisheries Institute (GCFI), Gosier, Guadeloupe 10 – 14 November 2008. CERMES MarGov Project Document 12. Centre for Resource Management and Environmental Studies, Barbados. 19 pp.

Basic practical information on climate change and adaptation was not reaching fishing communities. From the four country consultations it seems that this situation has improved only a little. There are, however, many useful resources for communicating on climate change available from all of the intergovernmental partner agencies in this study as well as NGOs. There have been innovative trials to communicate using dance, song and theatre that may appeal to young people and better prepare the next generation[88].

The country consultations reinforced the importance of building skills and experience through learning-by-doing. A fisheries example is the way in which GCFI[89] partnered with the SPAW Programme of the UNEP CEP to make available a Small Grant Fund to promote sustainable fishing practices and alternative livelihoods for fishers, much of this being used for fisher exchanges.

4.2.7 Universities and other collaborators

The roles of universities and researchers were addressed especially in the UWI Mona consultation. The International Community-University Research Alliance (I-CURA) project on "Managing Adaptation to Environmental Change in Coastal Communities: Canada and the Caribbean", links communities and university researchers from Canada with those in the Caribbean in support of research on coastal adaptation to environmental change. This includes the impacts of storm surge and sea-level rise on susceptible coastal communities in locations such as the Belize Barrier Reef; Georgetown, Guyana; Grande Riviere, Trinidad and Tobago; and Bequia, St. Vincent and the Grenadines. Fishing and aquaculture is not the primary focus, but the results will be relevant and this illustrates partnerships that are possible. Regional and national research agendas should be integrated.

Some persons in the consultations were in favour of pursuing more South-South links as priority. The consultant briefly assessed this in communication with a colleague in the South Pacific region and confirmed a high level of interest, especially in integrated community-based initiatives[90]. The possible resurgence of Technical Cooperation between Developing Countries (TCDC[91]) perhaps spearheaded by FAO was mentioned as a means of developing appropriate partnerships and capacity.

The International Federation of Red Cross Societies (IFRCS) is implementing climate change projects to assess vulnerability and risk, and build community level resilience to disasters in countries such as Grenada, Antigua and Barbuda and St. Kitts and Nevis. In the Grenada consultation the Red Cross representative stressed the importance of paying more attention to communities and raising awareness such as being done with HIV / AIDS. It does not appear that full use is being made of organisations such as the Red Cross and PAHO, and service clubs such as Lions, Rotary, Kiwanis and Optimists in DRM and CCA. Youth, religious, sport and other community-based organisations also need to be brought closer into partnership.

4.2.8 Legal-institutional arrangements

Legal-institutional arrangements exist or are planned in most places especially for DRM. CDEMA has provided model disaster legislation that countries are using to revise their laws. Even without this, the practice of 'hurricane preparedness' is well institutionalised and fully involves marine fisheries in

[88] CANARI. 2009. Communicating climate change: A toolbox for local organisations in the Caribbean. Port of Spain, Trinidad and Tobago: Caribbean Natural Resources Institute.
[89] http://www.gcfi.org
[90] Hugh Govan, independent researcher and Foundation of the Peoples of the South Pacific International
[91] http://www.fao.org/focus/e/tcdc/intro-e.htm

most countries. A constraint to adaptation may be that most fisheries authorities are still stuck in the 'preparedness' mode activated primarily for late response and early recovery. The countries visited, despite all having had recent disaster experiences (mainly storms and floods), admitted that CCA and DRM were not priority concerns in fisheries and aquaculture. Without active fisheries management plans it is difficult to determine exactly where CCA and DRM will fall in the scheme of things apart from being included primarily in external ad hoc initiatives.

Where there are specific DRM policies and legislation, such as in Belize, those directly underpinning DRM illustrate the shift from reactive disaster management systems to a more proactive disaster risk management systems which assign importance to adaptation and mitigation as compared to primarily response. In Belize a 10-year National Hazard Mitigation Plan, emphasizing multi-sector, integrated, coordinated approaches was adopted in 2007. Agricultural aspects include increasing the resilience of people's livelihoods in the rural areas where fishing and aquaculture are important. Exposure to capacity building in Comprehensive Disaster Management (CDM) was deemed to be beneficial.

Belize has a draft National Aquaculture Policy and Plan along with legislation and a zoning schedule. Guyana also has a plan and Jamaica has in preparation a Land and Water Use Development Plan and Blue Print for an Aquaculture Action Plan. CCA and DRM do not feature prominently in the available plans. It is unclear the extent to which they will be included in the Jamaica plan but it is likely given the significant damages that the sector has suffered from the impacts of several hurricanes.

4.2.9 Resource valuation

Consultation participants noted that more resource valuation studies are being done to improve evidence-influenced policy decision-making that takes into account ecosystem services and long term benefits[92]. They indicated that having such information available for decision-making could be useful in persuading policy-makers to spend more on good environmental management a core component of mainstreamed CCA and DRM. Of particular note was the value of properly managing coral reefs[93].

A recent review examined the influence of coastal economic valuations in the Caribbean. Conclusions were mixed[94]. It appears that several contextual and external factors influence the extent to which the findings and recommendations of valuations receive attention at the policy level and achieve desired outcomes. Clearly this is an area that requires more attention, including examining constraints at the science-policy interface[95].

4.2.10 Fisheries data

The Caribbean Fisheries Information System (CARIFIS) is a fisheries database used in many of the 17 CRFM members to store information mainly on fisheries catch and effort. Training workshops are occasionally held to build capacity, but the region is still relatively data poor and capacity limited.

[92] Schuhmann, P. W. 2012. The Valuation of marine ecosystem goods and services in the Wider Caribbean Region. CERMES Technical Report No 63. 57 pp

[93] Burke, L., S. Greenhalgh, D. Prager and E. Cooper. 2008. Coastal capital–Economic Valuation of Coral Reefs in Tobago and St. Lucia. World Resources Institute Working Paper. Washington DC: World Resources Institute.

[94] Kushner, B., R. Waite, M. Jungwiwattanaporn, and L. Burke. 2012. Influence of Coastal Economic Valuations in the Caribbean: Enabling Conditions and Lessons Learned. Working Paper. Washington, DC: World Resources Institute

[95] McConney, P., L. Fanning, R. Mahon and B. Simmons. 2012. Survey of the regional science-policy interface for ocean governance in the Wider Caribbean Region. Centre for Resource Management and Environmental Studies, University of the West Indies, Cave Hill Campus, Barbados, CERMES Technical Report No 51. 46p.

Data sharing was said to be an issue even at the national level amongst agencies with responsibility for aquatic resources, CCA and DRM. National data sets are annually put to the test in the CRFM fish stock assessments that form part of the scientific meeting. If better fisheries models are to contribute to adaptive capacity and include climate considerations[96], then data quantity and quality will need to improve. Different data may need to be collected or existing data processed differently if fisheries and climate scientists are to engage in data exchanges. For example, UNDESA points out that Grenada's exports of parrotfish to Martinique undermine reef resilience but the actual amounts of fish are only roughly estimated[97]. Monitoring of harvest as well as trade down to species or species group may be required. Fortunately, trends in seafood traceability favour this level of detail.

4.2.11 Insurance

Recent FAO reviews suggest that insurance remains a concern in effecting risk reduction in capture fisheries[98] and aquaculture[99] globally. There are, however, practices and experiences in other parts of the world that can be drawn upon for lessons and adaptation[100].

In the country consultations fishermen noted the difficulty in obtaining and affording insurance. Agriculture agencies and freshwater aquaculturists noted the advances that CCRIF is making in offering new products to governments, but also commented on the difficulty in measuring some of the parameters sufficiently accurately to provide the necessary evidence such as with rainfall intensity and flooding. The CCRIF does not have any direct products specifically targeted at the fisheries sector but recognizes the demand and is currently aiming to develop micro-insurance products across the region for low-income groups and to specifically link these products with DRR measures[101]. This would be a significant advance. The challenge of insurance for small-scale fisheries has been discussed at the Agriculture Sub-Sector Committee/Technical Management Advisory Committee and will remain an item for consideration.

Inadequate time series data on fishing fleets, small aquaculture operations, and damage to these sectors by hurricanes and other disasters hinder insurers and re-insurers that could provide cover in the Caribbean. Fisheries and aquaculture insurance schemes operating in other parts of the world were established by providing the financial sector with information for risk assessments.

Unemployment benefits from state-run national insurance may be paid to persons who lose their jobs as a result of a disaster. Since this is paid only to registered employees such as may be expected in larger fish processing plants and aquaculture farms. However, the majority of people in fishing and aquaculture are self-employed and most do not contribute to national insurance.

---

[96] Lehodey, P. F. Chai, and J. Hampton. 2003. Modelling climate-related variability of tuna populations from a coupled ocean-biogeochemical population dynamics model. Fisheries Oceanography 13:483-494

[97] UNDESA. 2012. Climate Change Adaptation in Grenada: Water Resources, Coastal Ecosystems and Renewable Energy. United Nations Department of Economic and Social Affairs

[98] Van Anrooy, R., I.U. Ahmad, T. Hart, M. Hotta, Y. Ping, W. Yang, T. Shipton, C. Benoit, R. Ruchismita, S. Upare and S.V. Siar. 2009. Review of the current state of world capture fisheries insurance. FAO Fisheries and Aquaculture Technical Paper. No. 510. Rome, FAO. 162p.

[99] Van Anrooy, R., P.A.D Secretan, Y. Lou, R. Roberts and M. Upar. 2006. Review of the current state of world aquaculture insurance. FAO Fisheries Technical Paper. No. 493. Rome, FAO. 92p.

[100] Hotta, M. 1999. Fisheries insurance programmes in Asia: experiences, practices and principles. FAO Fisheries Circular. No. 948. Rome, FAO. 54p

[101] Ekhosuehi Iyahen, Supervisor, Caribbean Catastrophe Risk Insurance Facility, personal communication

4.2.12 Interests of aquaculturists

Aquaculturists for food fish and ornamentals in Jamaica expect to benefit from measures intended for agriculture DRM, but they also have conflicts with agriculture and water resource management over vulnerabilities to flooding caused by poor drainage and pollution hazards from agrochemical abuse. They maintain that aquaculture has characteristics that prevent it from being fully aligned with other land and water uses. Earthquakes and tsunamis are the hazards for which they are least prepared. The indirect pathways of climate change impacts such as through higher energy and feed costs are also of particular concern since some see few means of mitigation or adaptation available at present.

In Belize, aquaculture farms around the Placencia Lagoon are collaborating with the World Wildlife Fund to develop green adaptive technologies for aquaculture facility construction and operation. It is anticipated that best practices will be developed and adopted by the entire aquaculture industry. Some measures include vegetation buffers, reduced chemical use, better effluent treatment and the like. This will reduce the impacts of climate and disasters on the farms and the impacts of the farms on the surrounding areas of wetland.

4.2.13 Safety at sea

Grenada has implemented a vessel monitoring system (VMS) for larger fishing boats. This serves for both MCS and safety at sea since accurate position information enhances response options and time as may be needed in cases of life threatening rough seas. That country and others have been upgrading marine radio communications and safety at sea training which facilitate early warning systems (EWS) and rescue. More countries are enforcing the registration and licensing of fishing vessels which aids in maintaining an accurate database from which damages and losses can be estimated if necessary.

Safety at sea training events are appropriate platforms for increasing the awareness to fishers about climate and disasters. Issues of vessel design, loading and stability can be drawn in to the discussion on personal safety. The Caribbean Network of Fisherfolk Organisations is interested in taking part in an investigation to determine how best to adapt vessels and gear to changing climate and disasters[102].

4.2.14 Jurisdictions and partnerships

Overlapping, competing and conflicting government agency jurisdictions, such as prevalent in the coastal zone, were seen as major constraints to developing adaptation at the community or any other level. Better coordination and collaboration through national committees for disasters, climate change, environment, biodiversity and similar were urged. Most countries have legislation that requires or permits multi-stakeholder fisheries and/or aquaculture bodies. Few of these exist or are functioning.

Participants in consultations highlighted the Ministry of Finance as a key actor and gatekeeper for CCA and DRM. Finance ministries need to be better informed about the financial obligations that accompany being party to MEAs and having to meet reporting or implementation commitments. In Jamaica, for example, there were issues surrounding resources not reaching line departments even if total budgetary allocations were made and sufficient. Disbursement was the main challenge. An international donor noted issues with channelling disbursements as foreign policies, governments and political priorities changed. This is not peculiar to fisheries and aquaculture but these sectors are often on the margins of attention, low priority and frequently get cut first.

[102] Based upon email exchanges on the fisherfolk network e-group

Mechanisms for fisheries and aquaculture to be visible at high policy level may favour allocation of resources and development of adaptive capacity in the sectors. In Belize the Fisheries Department is expected to report on its risk management and climate change activities to the National Climate Change Committee and the Chief Meteorologist for inclusion in national communications to the UNFCCC. It is unclear whether such visibility is encouraged in all CRFM members, but it should be.

Financing new approaches to climate resilient development such as in emerging low carbon and green economy initiatives increasingly involves the private sector, and especially corporations that are well-financed and able to invest in new technologies. Green income-generating activities and job-creation opportunities are becoming more important such as in the Grenada Strategic Program for Climate Resilience (SPCR). The role of fishing and aquaculture enterprises is unclear and requires attention.

4.2.15 Donor relationships

Donor relationships were openly discussed in the country consultations. Here "donors" included big international NGOs, aid agencies and UN agencies. The donors indicated the need for more regional or sub-regional CCA and DRM proposals based on evidence and sound implementation strategies for delivering achievable outcomes. They had received few or no fisheries and aquaculture proposals, but agreed that these sectors were important in the national efforts which were often aimed at agriculture. A number of implementing government and civil society agencies pointed out that short-term donor deliverables were constraining capacity development and that more, long-term framework programme funding was needed in order to work with communities at the appropriate pace for sustainability. The CARIBSAVE representative in one meeting described their strategy of working with only a limited number of communities until success was achieved despite pressure from many quarters to spread the activities among additional locations. Pressure to do this in marine fisheries can be high and political.

Dominica, Grenada, Haiti, Jamaica, Saint Lucia and St Vincent and the Grenadines are involved in the Pilot Program for Climate Resilience (PPCR), the adaptation funding window of the Climate Investment Fund (CIF) established by the multilateral development banks (MDBs) to finance climate change support for their developing member countries (DMCs). PPCR seeks to mainstream climate change adaptation into national development planning processes through a long-term programmatic approach which, ideally, frames all donor climate change adaptation interventions. Funds are allocated for the preparation of a Strategic Program for Climate Resilience (SPCR) and for implementation of the Caribbean pilot program in the identified key vulnerable sectors. In Grenada the PPCR activities include implementation of capacity building activities for the health, agriculture, tourism, environment, water, forestry and fisheries sectors. All PPCR-related activities will be advised by the National Climate Change Committee[103].

4.2.16 FAO assistance

FAO has been a partner in several initiatives related to CCA and DRM in fisheries and aquaculture. See some examples in Table 4.12. Most, however, are labelled as agriculture activities such as the DRM plans completed (e.g. Jamaica) and in preparation (e.g. Guyana). For the latter country the FAO NMTPF 2012-2015 states that there will be a focus upon "Reducing vulnerability to natural disasters through the establishment and strengthening of Early Warning Systems and improving mitigation measures in the agricultural sector; and reducing recovery time from natural disasters through the

[103] PPCR Aide-Memoire 2010

development of DRM plans" (FAO 2010:20). At the Guyana consultation the FAO country representative indicated that the fisheries and inland aquaculture content would be substantial.

Table 4.12 Excel Extract Report from the FAO Field Programme Management Information System (FPMIS) 2010

Countries	Project Title	USD Budget	Project Objectives
Belize TCP/BZE/3202; 2008-2010	Improved national and local capacities for hurricane related disaster mitigation, preparedness and response in the agricultural sector	$473,763	Supporting small farmers in selected villages through the identification and demonstration of appropriate DRM technologies and practices (including exploring options for adoption of financial risk mitigation tools) and capacity building
Dominica TCP/DMI; unstated	Assistance to improve disaster risk management	$250,000	Hurricane disaster mitigation for the agricultural sector, including fisheries and forestry, enhanced and measures developed to reduce losses due to land degradation.
Jamaica TCP/JAM/3202 BABY02; 2008-2009	National Disaster Preparedness and Emergency Response Plan for the Agricultural Sector	$92,293	To assist the Government of Jamaica to: Review and assess the existing preparedness, response and recovery mechanisms of the agricultural sector to natural disasters. Prepare national disaster preparedness and emergency response plans
Saint Lucia TCP/STL/3202; 2009-2011	Enhanced capacities for disaster risk mitigation in agriculture, fisheries and forestry	$359,000	Improved service delivery capacities of agriculture, fishery and forestry line departments, and enhanced know how of farmers and fishermen organisations to implement natural hazard risk mitigation and preparedness measures

Realising that good conventional fisheries management and adaptive co-management addresses many of the issues encountered in climate variability and change leads to the conclusion that more attention needs to be paid to promoting responsible fisheries and deepening awareness of the CCRF. Several initiatives potentially support this direction, including the promotion of fisheries planning by CRFM.

4.2.17 Vulnerability assessments

More countries are conducting vulnerability assessments themselves, or having them performed upon them by external agencies. Coastal and rural communities are often included, bringing in fisheries and aquaculture. In the country consultations some organisations pointed out the mix and differences in methodologies being used, often linked to a future funding stream, can cause problems or result in what seems to be unnecessary duplication. The level of detail required, and hence the cost in time and money, was of less concern. However, some organisations remarked that funds for assessment and other studies could be better used for pilot projects or other examples of learning-by-doing. Some agencies acknowledged that aid agencies repatriate funds through such studies that employ their own staff or consultants from their geo-political constituency. This may be countered by national agencies collectively endorsing one excellent assessment and insisting on it being used by all where possible. A number of assessment methodologies, some developed or adapted to the Caribbean, are available[104].

4.2.18 Poverty and livelihoods

Poverty was raised as a challenge to be overcome in building adaptive capacity. Insight specific to CARICOM fisheries and aquaculture is available in the recently concluded CRFM poverty study[105]. It addressed hazards and coping strategies. Hurricanes and floods were the prevalent hazards. Responses as to whether or not sampled households had been impacted or not by environmental hazards reflect the geographic pattern of hurricane risk (Figure 4.5).

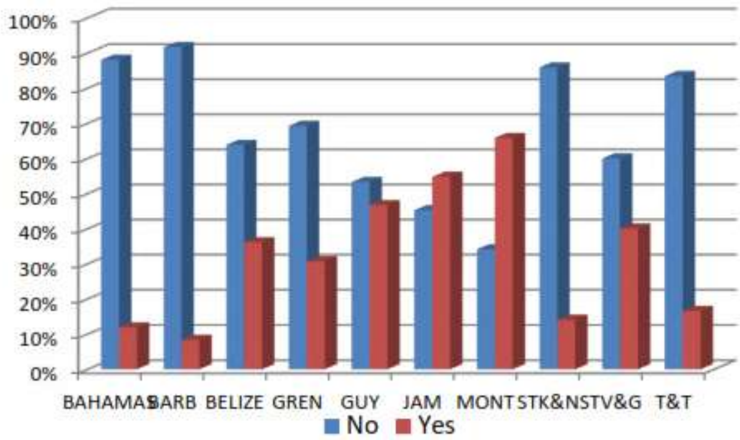


Figure 4.5 Responses to whether or not sampled households had been impacted by an environmental hazard (Source: CRFM 2012a)

Regarding coping strategies for getting their houses in order after an impact, respondents reportedly:

- Resorted to household savings (40%)
- Increased the number of working hours (18%)
- Borrowed money from family or friends (9%)
- Received assistance from state, church or NGOs (9%).

The full range of responses is shown in Figure 4.6. These may apply after moderate events in which there is no massive recovery effort. Increasing the number of working hours may imply additional fishing effort and possible worsening of overfishing, but the survey responses are not interpreted.

[104] Pulwarty, R. and N. Hutchinson. 2008. Vulnerability and capacity assessment methodology: A guidance manual for the conduct and mainstreaming of climate change vulnerability and capacity assessments in the Caribbean. Caribbean Community Climate Change Centre, Belmopan, Belize

[105] CRFM. 2012. Diagnostic Study to Determine Poverty Levels in CARICOM Fisheries Communities – Technical Document. CRFM Technical & Advisory Document – Number 2012 / 3. Volume I, 398p.

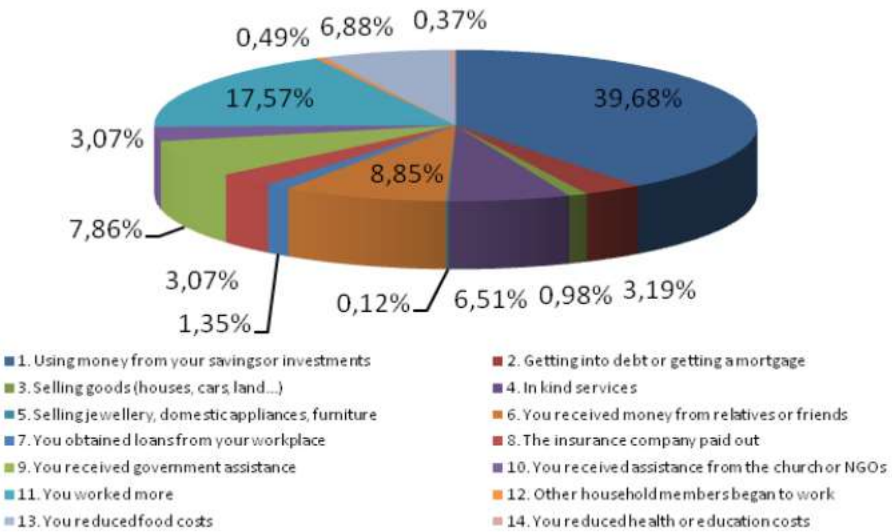


Figure 4.6 Coping strategies used after disasters
(Source: CRFM 2012a)

The poverty study lists the top concerns of respondents in the fishing industries of ten countries. The issues of climate and disasters do not make the list, although indirect pathways could be linkages. In addition to the CRFM study there are several hundred publications in the international literature that link fisheries to climate change and poverty[106].

Livelihoods were discussed extensively in the country consultations. Several agencies were working at the community level to find viable alternative or supplementary livelihoods for inshore fishermen especially. Participants identified some constraints to this direction of developing adaptive capacity:

- Reluctance to entirely leave fishing as a way of life
- Limited formal education reduces feasible options
- Limited education also restricts training for options
- Alternatives (e.g. tourism) are also fairly vulnerable
- Period required to work on alternatives is long term

Some participants pointed out that there is little evidence of alternative livelihoods being sustainable. This led, in one meeting, to a broader discussion on the need to document successes in the Caribbean and to celebrate them for global attention. Lack of success stories and tendency not to share successes was said to have worked against efforts to develop adaptive capacity and reinforced an image of the Caribbean requiring external assistance. The CRFM poverty study offers few insights into alternative livelihoods for the poor, but it outlines a method of livelihood analysis of which they are several. The project on the Future of Reefs in a Changing Environment[107] is one that includes livelihoods analysis in connection to coral reef fisheries and climate change adaptation.

4.2.19 Gender

The Regional Framework and IP acknowledge that gender needs to be mainstreamed or at least taken more into account. The consultations indicated that this was happening, but not always in a systematic manner. Participants described how the division of labour and ownership of assets were often

[106] Allison et al (2005)
[107] http://www.force-project.eu/

gendered. In Jamaica, women were playing major roles in fisheries (boat ownership and postharvest) from the background. They were not vocal but were very influential both in the industry and in workshops and planning events to organise and mobilise the communities. Participants suggested that gender analysis would assist their understanding of how best to design interventions. Much guidance is easily available for this[108].

ECLAC provides a gender perspective on the impact of Hurricane Ivan on Grenada[109]. Food security and child care are two major concerns. There were clear differences in the income-earning abilities of men and women in the reconstruction period. Inequalities are significant taking into consideration the proportion of poor female-headed households in some fishing and rural communities. One must beware, however, applying global gender stereotypes and gendered dimensions of CCA and DRM to the Caribbean. Caribbean women have proven themselves quite capable, adaptive and resilient under stressful conditions. In many cases it is men, particularly unemployed youth, who require attention as the term gender implies in addition to resolving the inequalities faced by women.

4.2.20 Regional Response Mechanism

The Regional Response Mechanism (RRM) is an arrangement for coordinating disaster responses among CDEMA Participating States, and regional and international agencies. The RRM and CDEMA's Regional Coordination Plan could be instrumental in strengthening the livelihoods analytical focus of damage assessments and recovery in fisheries and aquaculture. There are several ways in which the interfaces between the RRM and the fisheries and aquaculture sector can be improved. These include, but are not limited to:

- Incorporation of DRM into fisheries and aquaculture plans with attention to RRM procedures
- Maintaining comprehensive of fisheries and aquaculture enterprises to facilitate assessments
- Operating fisheries telecommunications systems for early warning, response and recovery
- Establishing community-based focal points for rapid needs assessments following impacts
- Compiling lists of fisheries and aquaculture experts available to assist the CDEMA teams
- Including "build back better" sections in all fisheries and aquaculture management plans

4.2.21 Coastal and fishery habitats

As noted previously, mainstreaming CCA and DRM into good environmental management will address many of the potential impacts. Both soft and hard coastal protection methods are in use throughout the Caribbean. Given the uncertainty of future climate and disasters these should be precautionary. The notion of managing entire coasts or large sections such as through seascapes rather than just MPAs is and adaptive measure being considered in Grenada. The Belize barrier reef system network of protected areas also assists by scaling up management. The eastern Caribbean does not have a true network of protected areas by ecological design but there social networking such as via the Caribbean Marine Protected Area Network and Forum (CaMPAM)[110] which serves to increase human adaptive capacity.

---

[108] GGCA. 2009. Training Manual on Gender and Climate Change. International Union for Conservation of Nature (IUCN), United Nations Development Programme (UNDP) and the Global Gender and Climate Alliance (GGCA).

[109] ECLAC. 2005. Grenada: A Gender Impact Assessment of Hurricane Ivan – Making the Invisible Visible. Port-of-Spain: The Economic Commission for Latin America and the Caribbean.

[110] http://campam.gcfi.org/campam.php

The project known as At the Water's Edge (AWE), led by The Nature Conservancy (TNC) focuses on coastal resilience in Grenada and St. Vincent and the Grenadines using what it terms Ecosystem-based adaptation (EBA) in a five-year project[111]. It seems to address deficiencies identified by participants in the country consultations. It includes community level implementation over a reasonably long period, developing leadership, strong networking, use of indicators, and participatory monitoring and evaluation. This and similar projects may be worth post-evaluation and outcome mapping in order to enhance shared learning.

4.2.22 Technological innovation

Technological innovation will be a key aspect of adaptation in fisheries and aquaculture. Participants in the country consultations were concerned that insufficient attention was being paid to encouraging and financing practical innovation. Such innovation should also be part of the transition to greener and low carbon economies. Examples of adaptation in Dominica are monitoring and re-design of fish traps to investigate and reduce ghost fishing[112]. The latter is the problem of fish traps that keep on fishing when lost or abandoned at sea. This problem is expected to increase with rough sea events. Another example is the award-winning Fisheries project using mobile phone communication technology in Trinidad and Tobago fisheries[113]. Other technology from other regions little or not used in the Caribbean includes submergible cage culture in aquaculture, new mooring and netting systems that prevent fish escapes in aquaculture, vessel construction, safety-at-sea technologies and more. In order to involve more private sector entities and NGOs in technology development, and to create green jobs, there must be more venture capital and high-risk micro-enterprise funding made available under favourable terms in addition to supporting services to increase the success rate of new start-up businesses focusing on fisheries and aquaculture.

4.2.23 Physical facilities

The need to climate-proof infrastructure such as public landing site facilities, fish processing plants, aquaculture facilities and other installations has been mentioned at a number of points. Land use planning or physical development planning can, and already has in some cases, allocate areas to vessel safe harbor and boatyards for repair. Such areas are often adjacent to fishing communities. It will be necessary to pay more attention to these aspects of adaptation in planning as inundation maps and hazard maps are generated. There is, however, a limit to which setbacks, engineering and other means can protect structures and operations from hazards, and this needs to be taken into account.

Small-scale fishing vessels are not allowed to enter some private or exclusive marinas that could provide shelter from storms and hurricanes. Political support and amended disaster legislation are required to make optimal use of available natural shelter, safe harbour and haul-out. Hauling and lifting equipment, such as, tractors and cranes, could be installed at or mobilized by the private sector for ports and landing sites to ensure that small vessels are moved to safer areas upon early warning as is done in Barbados.

---

[111] http://conserveonline.org/workspaces/climateadaptation/documents/grenadine-islands/
[112] Norris, N., J. Defoe and M. Ishida. 2011. Ghost Fishing by Lost and Derelict Fish Pots in the Commonwealth of Dominica. Proceedings of the Gulf and Caribbean Fisheries Institute 63:37-40
[113] http://cirp.org.tt/mfisheries/

4.2.24 Science-policy interface

A recent report on the science-policy interface in the Wider Caribbean Region states that policy-makers are likely to demand more marine scientific information on climate change, disasters, fish stock status and the like in the coming years[114]. It also reports that there are significant barriers at the science-policy interface from both the science and policy sides. This is relevant to fisheries and aquaculture since on the one hand it presents an opportunity to get the attention of policy-makers through the increasing demand, but on the other it means that the challenges in doing so must be addressed. Arrangements such as the CRFM, CDEMA, CCCCC and WECAFC working groups on various topics provide a means of addressing these issues, but only if designed to do so. CCA and DRM can be used to move towards more evidence-influenced (even if not evidence-based) policy in fisheries and aquaculture. This provides another incentive for mainstreaming CCA and DRM into fisheries and aquaculture policy and management plans while the demand for science remains high.

4.3 Conclusion

The above analysis provides CCA/DRM perspectives on vulnerability and resilience in fisheries and aquaculture. A striking feature is that participants in consultations considered it unproductive to use an analysis by hazard or by productive sector to offer inputs. Their practical treatment of these topics is more integrated and comprehensive. While acknowledging the differences among the hazards and productive sectors they suggest that limited resources necessitate a combined approach. They also say that not enough is being done by themselves and external agencies to encourage pooling or sharing of resources and expertise and efforts on the ground to create critical masses of adaptive capacity and to reduce inefficiency and ineffectiveness. Their concerns lie more with institutional arrangements and governance than with technical matters at this time. The former constrains advance in the latter arena. Fishing industry participants in the country consultations stressed the need to improve institutional arrangements as priority, but they also indicated interest in technical matters such as fishing vessel and gear design, safety at sea and the re-location of vulnerable fisher households.

[114] McConney, P., L. Fanning, R. Mahon and B. Simmons. 2012. Survey of the regional science-policy interface for ocean governance in the Wider Caribbean Region. CERMES Technical Report No. 51. 46pp

5 MEASURES FOR CARIBBEAN FISHERIES AND AQUACULTURE

Having considered the conceptual or analytical frameworks, the impacts of climate and disasters, what the literature and stakeholders in CRFM countries are doing and want to do to increase adaptive capacity and reduce vulnerability…our attention can now turn to the recommended measures for Caribbean fisheries and aquaculture. These form the basis for the strategic action and programme proposals. Many, as came out clearly in the consultations, are not specific to any one hazard or type of hazards. Some are more suitable than others for initial design and implementation at either regional (including sub-regional, national or local levels). In most cases measures can be slightly adapted and then replicated to achieve economies of scale and opportunities for networked capacity and learning.

Below we provide a summary list of recommended measures indicating their anticipated scope of application (Table 5.1). Ideally, readers should determine the priorities for their country, situation, level of application and ability to engage based on their existing and proposed goals, plans and ongoing activities before considering the strategic actions and proposals. Not everything can be done, and certainly not all at once. In some cases there will be a clear logical sequence to capacity building, but in others several complementary activities may be undertaken simultaneously if there are the resources as well as the ability to sustain the benefits from such interventions. Incremental approaches may yield the highest levels of success, and good partnerships or networks are particularly important. The measures are not only for consideration and implementation by national governments and inter-governmental organisations. Local government (where it exists), civil society and the private sector should see roles to play in most of the measures. Utilise existing resources, particularly by networking capacity, since dependence upon external funding does not foster self-organisation and sustainability.

Table 5.1 Measures for Caribbean fisheries and aquaculture

Recommended measure	Remarks
REGIONAL LEVEL INITIATIVES	
1. Develop a protocol that specifically addresses integrating CCA and DRM into the CCCFP and national initiatives	CRFM leads, based on CCCFP approval by fisheries ministers
2. Engage the WECAFC SAG and Commission, and CLME Project to encourage WCR partnerships beyond CARICOM	CRFM and WECAFC can co-lead as appropriate
3. Ensure that the CLME IMS-REMP or similar draws upon climate and disaster databases to construct regional data	CRFM works with CLME and other databases on construction
4. Include institutional arrangements for CCA and DRM in fisheries and aquaculture in the CLME strategic action plan	CRFM can lead from position on SAP formulation team
5. Ensure that the policies and plans formulated under ACP Fish II contain meaningful provisions on CCA and DRM	CRFM in close collaboration with ACP Fish II and members
6. Based on EAF, engage the regional bodies for agriculture, tourism, transportation etc. to connect with the initiative	CLME Project, CEP and CSC cover these somewhat in WCR
7. Disseminate the IP, as modified by inclusion of fisheries and aquaculture, widely to all likely stakeholders	CRFM, CDEMA and CCCCC using a communication plan
8. Disseminate the CDEMA CCA2DRR tools (e.g. see G tool in refs.) and supporting material to all likely stakeholders	CRFM and CDEMA share the lead, involving NGOs, CBOs
9. Develop peer group training networks for the application of the CCA2DRR tools to create communities of practice	CRFM and CDEMA share the lead, involving NGOs, CBOs

Recommended measure	Remarks
10. Support the development of fisheries management plans and aquaculture plans that fully incorporate EAF, CCA and DRM	CRFM renewed effort with collaboration from WECAFC
11. Develop new partnerships to mobilize resources for CCA/ DRM programmes and projects within the aquatic sectors	CRFM leads countries but then downscales for implementation
12. Create user-friendly web-based interfaces for networking, communication and collaboration to be cost-effective	Regional design downscaled to accommodate national, local
13. Develop CCRIF products further, particularly for flooding and storm surge for which data for modelling are improving	CCRIF, aquaculture, fisheries and private insurance bodies
14. Institutionalise climate and disaster reporting in various WECAFC and CRFM fishery resource working groups	WECAFC and CRFM lead and fisheries authorities cooperate
15. Expand the CCCCC project database to include DRM and ensure it covers all levels of project, including by CBOs	CCCCC leads but needs local and national data uplinked to it
16. Develop linkages with high level regional and national multi-stakeholder policy bodies to elevate sector status	CRFM facilitates but countries need to lead with political will
17. Create CRFM research agendas with UWI and many other universities to drive demand-based interdisciplinary work	CRFM leads with UWI but the countries must play active role
18. Promote TCDC as a means of cost-effective south-south exchanges and capacity development especially via FAO	CRFM and FAO facilitate the country requirements for this
19. Prepare and bring into force DRM legislation using the CDEMA model and learn from locations with such laws	CDEMA and national disaster offices share lessons regionally
20. Implement the CCRF, especially integration of fisheries into coastal area management and participatory planning	CRFM and WECAFC assist national authorities, CNFO
21. Increase the content related to climate and disasters in fisheries and aquaculture related university courses	CRFM and UWI collaborate using material from CDEMA
22. Establish institutional arrangements in governance to link bi-directionally vertically from local to regional levels	CRFM Fisheries Forum and its members and observers assist
23. Determine data sharing required between fisheries stock assessment and climate models; initiate data exchanges	CRFM, CCCCC, UWI and national fisheries authorities with FAO
24. Conduct a multi-stakeholder review of CCA / DRM tools available to suggest a toolkit suitable for CRFM members	CRFM, CCCCC, CDEMA with national fisheries authorities and NGOs
25. Encourage fishing access agreements under the CSME and CCCFP to allow movement of fleets to legally follow fish	CRFM, fisheries authorities, OECS, CARICOM, CNFO
26. Encourage movement of capital under CSME and CCCFP to allow processing and marketing to go to where fish are	CRFM, fisheries authorities, OECS, CARICOM, CNFO
27. Develop post harvest processing and marketing capacity to use unfamiliar, altered season or more abundant species	CRFM, FAO, CNFO, private sector, fisheries authorities
NATIONAL LEVEL INITIATIVES	
28. Integrate and mainstream EAF, CCA and DRM into a combined strategy as part of fisheries and aquaculture development	Countries lead on reforming policy and planning content

Recommended measure	Remarks
29. Strengthen national mechanisms for coordinating multi-agency efforts at CCA and DRM in the aquatic sectors	Countries take lead, may need legal reform, high political will
30. Enhance knowledge of the Hyogo Framework of Action within the fisheries and aquaculture sectors	Countries lead via national disaster offices, NGOs, CBOs
31. Improve planning for rebuilding and rehabilitation in the aftermath of disasters so as to adapt and "build back better"	Country level benefitting from regional experience networking
32. Pursue longer term framework funding to extend project implementation periods for community interventions	National and NGOs working with donors of different types
33. Insert or increase more CCA and DRM content in schools located in coastal communities and in all fisher training	National fisheries, education and vocational training bodies
34. Invest in learning-by-doing approaches rather than mainly workshops so results can be included in social learning	National and local lead sharing lessons learnt regionally
35. Commit to well informed and participatory planning, implementation, monitoring and evaluation at all levels	National mainly for policy and planning framework reform
36. Include the aquatic sectors in low carbon, green economy and renewable energy initiatives wherever possible	Fisheries ministries lead green economy sector integration
37. Ensure that fisheries and aquaculture are well covered in SPCR/PPCR programming in the participating countries	Fisheries ministries and PPCR focal points with CRFM help
38. Exchange information among countries and communities on vulnerability assessment methods and models in use	Climate and disaster offices with international agencies
39. Prepare inventories and maps of safe harbour and haul-out sites annotated to communicate risk and response times	National disaster and fisheries authorities with local help
40. Engage service clubs and other bodies in civil society to assist in two-way communication on fisheries, aquaculture	National fisheries offices with NGO close collaboration
41. Enact or strengthen fisheries and aquaculture legislation to include provisions for adaptation and disaster emergencies	National authorities guided by disaster offices and CRFM
42. Re-train fisheries authorities to think beyond annual hurricane preparedness as their only DRM responsibility	National disaster offices along with fisheries offices, CRFM
43. Guide planning authorities and coastal developers to ensure that fisheries are not at risk from poorly done infrastructure	National physical planning and fisheries offices collaborate
44. Reserve some coastal safe havens for emergency boat haul out and repair beyond likely storm surge and inundation	National physical planning and fisheries offices collaborate
45. Climate proof fisheries and aquaculture infrastructure to the extent possible using both hard structures and soft measures	Physical planners, fisheries authorities, local private sector
46. Undertake gender analyses in fisheries and aquaculture to demonstrate usefulness in policy, planning, management	National gender and fisheries offices with UWI assistance
47. Require that climate and disaster risk analysis/management be a precondition for fisheries infrastructure construction	National physical planning and fisheries offices collaborate
48. Conduct resource valuation studies to include ecosystem services in decisions on the alteration of coastal habitats	National agencies perhaps with university and donor assistance
49. Pursue the provision of insurance products to fisheries and aquaculture enterprises by improving risk assessment etc.	National authorities, CCRIF and private sector companies

	Recommended measure	Remarks
50.	Manage watershed drainage to take advantage of increased rainfall such as by creating reservoirs stocked with fish	National water resources and fisheries management agencies
51.	Include inland aquaculture in sustainable land use, watershed and water resource management plans	Fisheries authorities with land and water agencies nationally
52.	Improve energy efficiency on all fishing vessels, in fish processing plants and on fish farms within green economy	Fisheries authority, energy and environmental agencies, users
53.	Intensify boat registration and licensing, vessel monitoring, safety at sea training and such preparatory measures	Fisheries authorities and fisher organisations collaborate
54.	Monitor recruitment variability linked to the environment in order to forecast likely fishery year class variability	Fisheries authorities, CRFM, universities, CNFO and fishers
55.	Focus more on indicators, decisions and adaptation than on quantitative models with parameters sensitive to uncertainty	Fishery authorities with CRFM and FAO / WECAFC guidance
56.	Mainstream CCA and DRM by including relevant agencies in Fisheries Advisory Committees and aquaculture bodies	Fisheries authorities backed by fisherfolk organisations, NGOs
LOCAL LEVEL INITIATIVES		
57.	Strengthen CCA and DRM linkages especially at local level in order to encourage synergistic interventions, messages	Local level with NGOs, CBOs but share regionally to learn
58.	Create action learning groups, learning networks or other means of mutual support and sharing for the initiatives	Local level with laterally and vertically integrated networks
59.	Document what coping strategies are or have been used for climate variability and disasters to inform interventions	Local level with NGOs, CBOs and then regional comparison
60.	Conduct vulnerability and capacity assessments to identify priorities for action and opportunities for joint action	Local and national level with regional sharing of results
61.	Conduct a technical analysis of vessel types and responsible fishing methods so as to optimise viable adaptation options	Local to regional level; CNFO interested in collaborating
62.	Develop and implement education/awareness specifically for fisherfolk and fish farmers on climate and disasters	Local level implementation of national education programme
63.	Follow on from the CRFM study to integrate poverty into fisheries and aquaculture policy and plans in pilot testing	Local communities, national poverty and fisheries agencies
64.	Ensure that the policies and plans developed under projects are ‘pro-poor’ and do not exacerbate poverty or inequality	Civil society local level groups and national poverty offices
65.	Establish / strengthen fisherfolk organizations involvement in DRM / CCA integrating social and gender considerations	Local coalitions of fisheries authority, NGOs, CBOs, UWI
66.	Establish systems for fishers to report unusual observations at sea and patterns in catches promptly via organisations	Local fisher groups, CNFO and national fisheries authorities
67.	Identify, share and use local and indigenous knowledge and good practices that remain relevant in the face of change	Local level NGOs, CBOs work with national agencies in field
68.	Manage and restore vegetation in watersheds to reduce sedimentation and restore or sustain ecosystem services	Forestry office, land use body, communities, NGOs, CBOs
69.	Promote fishing priority areas and local area management authorities to facilitate subsidiarity and self organisation	Local fishery groups, MPA bodies, fisheries authorities
70.	Allow for aquaculture expansion in freshwater and brackish	Fisheries, aquaculture and

Recommended measure	Remarks
habitats such as by integrated rice and fish or other culture	agriculture locally, nationally
71. Strengthen or examine tenure systems for rights over use of expanded water bodies in order to promote aquaculture	Land use agencies, indigenous groups, fisheries authorities
72. Monitor and regulate agrochemical use in flood zones to limit effects on aquaculture and downstream biodiversity	Agriculture, aquaculture and environment national agencies
73. Promote integrated household aquaculture in high rainfall rural areas using rainfall harvesting to obtain good supply	FAO, agriculture and fisheries authorities, local NGOs, CBOs

Mobilising selected, prioritised measures requires several iterative steps, with information exchange and negotiations among interested parties at each step. These include, but are not limited to, the following:

- Agree on the strategy and action plan (Volume 2) into which measured fit
  - This is to be based on the IP and other associated documentation
- Negotiate criteria for selecting measures for development into proposals
  - Criteria for selection can include
    - fit with national and regional policies and initiatives
    - expected levels of political will and hence support
    - scope of the desirable outcomes from the proposals
    - preferences for level or levels of implementation
    - anticipated time required to achieve the outcomes
    - likelihood of successful resource mobilisation
    - marketability and hence likelihood of engagement
    - suitability for collaboration and scaling up impacts
- Convert selected measures into specific programme proposals (Volume 3)
- Determine ownership and leadership needed to carry forward initiatives
- Establish the buy-in of all key stakeholders and strategic communication.

Volumes 2 and 3 recommend a strategy and action plan, and programme proposals, respectively.

6 REFERENCES AND FURTHER READING

Ahmad, R. 2007. Risk Management, Vulnerability and Natural Disasters in the Caribbean. A Report Prepared For The International Federation Of Red Cross. 43pp.

Baas S., S. Ramasamy, J. Dey DePryck and F. Battista. 2008. Disaster Risk management Systems Analysis. FAO, Rome.

Badjeck, C., E. H. Allison, A. S. Halls and N. Dulvy. 2010. Impacts of climate variability and change on fishery-based livelihoods. Marine Policy 34: 375–383

Bahadur A., M. Ibrahim and T. Tanner. 2010. The resilience renaissance: Unpacking of resilience for tackling climate change and disasters. Strengthening Climate Resilience Discussion Paper 1, Institute of Development Studies, Brighton, UK.

Barange, M. and R.I. Perry. 2009. Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture. In K. Cochrane, C. De Young, D. Soto and T. Bahri (eds). Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO. pp. 7–106.

Bell J. D., J. E. Johnson, and A. J. Hobday. 2011. Vulnerability of tropical pacific fisheries and aquaculture to climate change. Secretariat of the Pacific Community, Noumea, New Caledonia.

Berkes, F. and C. Folke, eds. 1998. Linking social and ecological systems: management practices and social mechanisms for building resilience. Cambridge University Press, Cambridge, UK. 459 pp

BirdLife International. 2010. Ecosystem Profile: the Caribbean islands biodiversity hotspot. CEPF

Bueno, R., C. Herzfeld, E. A. Stanton and, F. Ackerman. 2008. The Caribbean and Climate Change: The Costs of Inaction. Massachusetts, USA: Stockholm Environment Institute-US Center, Global Development and Environment Institute, Tufts University.

Burke, L. and J. Maidens. 2004. Reefs at Risk in the Caribbean. Washington, DC: World Resource Institute.

Burke, L., K.Reytar, M. Spalding and A. Perry. 2011. Reefs At Risk Revisited. Washington, DC: World Resource Institute 130 pp

Burke, L., S. Greenhalgh, D. Prager and E. Cooper. 2008. Coastal capital–Economic Valuation of Coral Reefs in Tobago and St. Lucia. World Resources Institute Working Paper. Washington DC: World Resources Institute.

Burnett Penn, A. 2011. Position Paper - The Caribbean Overseas Territories Declaration on Climate Change. Technical Report 5C/ECACC-10-10-1. Caribbean Community Climate Change Centre, Belmopan, Belize

Cambers. C., R. Claro, R. Juman, and S. Scott. 2008. Climate change impacts on coastal and marine biodiversity in the insular Caribbean: Report of Working Group II, Climate Change and Biodiversity in the Insular Caribbean. CANARI Technical Report No.382: 87pp

Campbell, D., D. Barker, and D. McGregor. 2011. Dealing with drought: Small farmers and environmental hazards in southern St. Elizabeth, Jamaica. Applied Geography 31:146-158.

CANARI. 2009. Communicating climate change: A toolbox for local organisations in the Caribbean. Port of Spain, Trinidad and Tobago: Caribbean Natural Resources Institute.

Carby, B. 2012. Synchronising Climate Change and Regional Disaster Risk Reduction. Presentation at CSGM Data Rescue and Climate Change Workshop, UWI Mona Campus.

CARICOM. 2010. Agreement establishing the Caribbean Community Common Fisheries Policy. Caribbean Community.

CCCCC. 2009. Climate Change and the Caribbean: A Regional Framework for Achieving Development Resilient to Climate Change (2009-2015). Caribbean Community Climate Change Centre, Belmopan, Belize

CCCCC. 2011. Regional Diagnostic: Climate Change and Development Research Capacities and Regional Priorities in the Caribbean. Caribbean Community Climate Change Centre, Belmopan, Belize.

CCCCC. 2012. Delivering transformational change 2011-21: Implementing the CARICOM `Regional Framework for Achieving Development Resilient to Climate Change. Caribbean Community Climate Change Centre, Belmopan, Belize

CCRIF. 2010. Enhancing the Climate Risk and Adaptation Fact Base for the Caribbean: Preliminary results of the ECA Study. Grand Cayman, Cayman Islands: Caribbean Catastrophe Risk Insurance Facility. Retrieved from http://www.ccrif.org/sites/default/files/publications/ECABrochureFinalAugust182010.pdf

CDEMA. 2010. Mapping the Enhanced Comprehensive Disaster Management Programme Framework to the Climate Change and the Caribbean: A Regional Framework for Achieving Development Resilient to Climate Change. Bridgetown: CDEMA 3 pp.

CDEMA. 2010. The Regional Programme and Plan of Action for Climate Change Adaptation and Disaster Risk Reduction for the Mainstreaming Climate Change into Disaster Risk Management for the Caribbean Region (CCDM) Project. Bridgetown: CDEMA 38 pp.

CDEMA. 2011a. Climate Smart Disaster Risk Management Module, Facilitators and Participant's Handbooks. Caribbean Disaster Emergency Management Agency. Lodge Hill. Barbados

CDEMA. 2011b. The Guidance Tool: A Manual for Mainstreaming Climate Change Adaptation into the CDM Country Work Programme. Caribbean Disaster Emergency Management Agency, Barbados.147pp.

CDEMA. 2011c. Climate Smart Community Disaster Management Programme. Caribbean Disaster Emergency Management Agency, Barbados. 56pp.

CDERA, 2002. Report of the Brainstorming Workshop on Adaptation to Climate Change in Caribbean Disaster Risk Management, Barbados, June 2002

CDERA. 2007. CDM Strategy and Programme Framework 2007-2012. Caribbean Disaster Emergency Response Agency, Barbados.

CDERA and CDB. 2005. Legislative Review and Institutional Capability Assessment for Hazard Mitigation within the Framework of the Post-Ivan Reconstruction Programme - Grenada. Caribbean Disaster Emergency Response Agency and Caribbean Development Bank.

Centella, A. 2010. Regional climate modelling in the Caribbean. Economic Commission for Latin America and the Caribbean–Sub-regional Headquarters for the Caribbean. Retrieved from http://www.eclac.org/publicaciones/xml/2/39862/LCARL.265.pdf.

CERMES. 2009. Report of the Fishers Forum: "Climate change and small-scale fisheries in the Caribbean" at the 61st Gulf and Caribbean Fisheries Institute (GCFI), Gosier, Guadeloupe 10 - 14 November 2008. CERMES MarGov Project Document 12. Centre for Resource Management and Environmental Studies, Barbados. 19 pp.

Chakalall, Y.S. and L. J. Walling. 2009. Incorporating Business Continuity and Disaster Recovery (BC/DR) in Governance and Planning Systems of Caribbean SIDS. Presented at the 10th Annual SALISES Conference - Navigating Risks and Building Resilience in Small States. March 25-27, 2009 Cave Hill Campus, Barbados.

Chen. A., M. Taylor, A. Centella, D. Farrell. 2008: Climate trends and scenarios for climate change in the insular Caribbean: Report of Working Group I, Climate Change and Biodiversity in the Insular Caribbean. CANARI Technical Report No.381: 63pp.

Cochrane, K.; De Young, C.; Soto, D.; Bahri, T. (eds). 2009. Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO. 212p

Colley, M., Haworth, A., Firth, J. 2011. Regional Diagnostic: Climate Change and Development Research Capacities and Regional Priorities in the Caribbean. Caribbean Community Climate Change Centre, Belize

CRFM. 2012a. Diagnostic Study to Determine Poverty Levels in CARICOM Fisheries Communities – Technical Document. CRFM Technical & Advisory Document – Number 2012 / 3. Volume I, 398p.

CRFM. 2012b. Diagnostic Study to Determine Poverty Levels in CARICOM Fishing Communities - Policy Document. CRFM Technical & Advisory Document, Number 2012 / 3, Volume II. 25p.

Daw, T.; Adger, W.N.; Brown, K.; Badjeck, M.-C. 2009. Climate change and capture fisheries: potential impacts, adaptation and mitigation. In K. Cochrane, C. De Young, D. Soto and T. Bahri (eds). Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO. pp.107-150.

Day. O. 2009. The impacts of climate change on biodiversity in Caribbean islands: what we know, what we need to know, and building capacity for effective adaptation. CANARI Technical Report No.386: 28pp

De Silva, S.S. and Soto, D. 2009. Climate change and aquaculture: potential impacts, adaptation and mitigation. In K. Cochrane, C. De Young, D. Soto and T. Bahri (eds). Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO. pp. 151-212.

De Young, C., A. Charles and A. Hjort. 2008. Human dimensions of the ecosystem approach to fisheries: an overview of context, concepts, tools and methods. FAO Fisheries Technical Paper. No. 489. Rome, FAO. 152p.

Dolan, A.H. and I.J. Walker, 2006: Understanding vulnerability of coastal communities to climate change related risks. J. Coastal Res., 39, 1317-1324.

ECLAC. 2005. Grenada: A Gender Impact Assessment of Hurricane Ivan – Making the Invisible Visible. Port-of-Spain: The Economic Commission for Latin America and the Caribbean.

ECLAC. 2011. The Economics of Climate Change in the Caribbean. Port-of-Spain: The Economic Commission for Latin America and the Caribbean

Fanning, L., R. Mahon and P. McConney. [Eds]. 2011. Towards marine Ecosystem-Based Management in the Wider Caribbean. Amsterdam University Press, Netherlands. 428pp.

FAO. 1995. Code of Conduct for Responsible Fisheries. FAO, Rome. 41 pp

FAO. 2003. The ecosystem approach to fisheries. Issues, terminology, principles, institutional foundations, implementation and outlook. FAO Fisheries Technical Paper No. 443. Rome 71pp.

FAO. 2008. Good Agricultural Practices for Climate Risk Management in Grenada - Summary Report. Rome: The Food and Agriculture Organization of the United Nations - FAO.

Farrell, D., A. Trotman, and C. Cox. 2010. Drought early warning system and risk reduction: A case study of the Caribbean drought of 2009-2010, Global assessment report on disaster risk reduction: United Nations International Strategy for Disaster Reduction (ISDR).

Gero, A., K. M´eheux, and D. Dominey-Howes. 2011. Integrating community based disaster risk reduction and climate change adaptation: examples from the Pacific. Nat. Hazards Earth Syst. Sci., 11: 101–113.

GFDRR. 2010. Disaster Risk Management in Latin America and the Caribbean Region: GFDRR Country Notes, Grenada. Washington, USA: Global Facility for Disaster Reduction and Recovery.

GGCA. 2009. Training Manual on Gender and Climate Change. International Union for Conservation of Nature (IUCN), United Nations Development Programme (UNDP) and the Global Gender and Climate Alliance (GGCA).

Gillet, V. and G. Myvette. 2008. Vulnerability and Adaptation Assessment of the Fisheries and Aquaculture Industries to Climate Change. Belize National Meteorological Service, Belize

Glemarec, Y. 2011. Catalysing Climate Finance: A Guidebook on Policy and Financing Options to Support Green, Low-Emission and Climate-Resilient Development. United Nations Development Programme, New York, NY, USA.

Government of Anguilla 2011. Green paper: a working document to assist with the formulation of a Climate Change Strategy for Anguilla. Caribbean Community Climate Change Centre, Belmopan, Belize

Government of Anguilla. 2011. Transforming to a climate-resilient, energy, efficient and low carbon economy: Anguilla`s Climate Change Policy (draft). Caribbean Community Climate Change Centre, Belmopan, Belize

Government of Grenada. 2011. Grenada Strategic Program for Climate Resilience (SPCR). St. George’s: Government of Grenada

Government of Guyana. 2010. Transforming Guyana's economy while combating climate change. Office of the President, Republic of Guyana.

Gray, G. and Montserrat Ministry of Agriculture, Land, Housing and the Environment. 2010. Montserrat Climate Change Issues Paper: Towards the Formulation of a National Climate Change (Adaptation) Policy and Action Plan. Caribbean Community Climate Change Centre, Belmopan, Belize

Haughton, M., R. Mahon, P. McConney, G.A. Kong, and A. Mills. 2004. Establishment of the Caribbean regional fisheries mechanism. Marine Policy 28:351–359

Hernández-Rodríguez, A., Alceste-Oliviero, C., Sanchez, R., Jory, D., Vidal, L. & Constain-Franco, L.-F. 2001. Aquaculture development trends in Latin America and the Caribbean. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 317-340. NACA, Bangkok and FAO, Rome.

Hotta, M. 1999. Fisheries insurance programmes in Asia: experiences, practices and principles. FAO Fisheries Circular. No. 948. Rome, FAO. 54p.

IPCC. 2007. Climate Change 2007: Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge, UK and New York, NY, USA

IPCC. 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B et al[115] (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.

Jones E.B., Bisek P.A., Ornstein C. 2001. Comprehensive Disaster management in the Caribbean: Baseline study. CEDERA report under the Comprehensive Approach for Disaster Management in the Caribbean Project.

Kerr, S.A., 2005. What is small island sustainable development about? Ocean and Coastal Management 48:503-524.

Kooiman, J., M. Bavinck, S. Jentoft and R. Pullin. (eds) 2005. Fish for Life: Interactive Governance for Fisheries. MARE Publication Series No. 3. Amsterdam: University of Amsterdam Press.

Kushner, B., R. Waite, M. Jungwiwattanaporn, and L. Burke. 2012. Influence of Coastal Economic Valuations in the Caribbean: Enabling Conditions and Lessons Learned. Working Paper. Washington, DC: World Resources Institute.

[115] “et al” used in reference list for publications with more than ten authors or editors

Lehodey, P. F. Chai, and J. Hampton. 2003. Modelling climate-related variability of tuna populations from a coupled ocean-biogeochemical population dynamics model. Fisheries Oceanography 13:483-494.

Lehodey P, et al. 2006. Climate variability, fish, and fisheries. Journal of Climate 19:5009–30.

Linacre, N., A. Kossoy and P. Ambrosi. 2011. State and trends of the carbon market 2011. World Bank, Washington, DC.

Mahon, R. 2002. 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.

Medeiros, D., H. Hove, M. Keller, D. Echeverría and J. Parry. 2011. Review of Current and Planned Adaptation Action: The Caribbean. International Institute for Sustainable Development (IISD). 159pp.

McConney, P., L. Nurse and P. James. 2009. Impacts of climate change on small-scale fisheries in the eastern Caribbean: a final report to IUCN. CERMES Technical Report No. 18. 36pp

McConney, P., L. Fanning, R. Mahon and B. Simmons. 2012. Survey of the regional science-policy interface for ocean governance in the Wider Caribbean Region. CERMES Technical Report No. 51. 46pp

Mimura, N., L. Nurse, R.F. McLean, J. Agard, L. Briguglio, P. Lefale, R. Payet and G. Sem, 2007: Small islands. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 687-716.

MPDEH. 2003. Saint Lucia National Climate Change Policy and Adaptation Plan. Ministry of Physical Development, Environment and Housing. [Retrieved from www.climatechange.gov.lc/NCC_Policy-Adaptation_7April2003.pdf]

Mitchell, T and M., Ibrahim. 2010. Climate Smart Disaster Risk Management In Brief. Briefing paper. Institute of Development Studies, Brighton, UK

Mitchell, T., M. Van Aalst and P. Silva Villanueva. 2010. Assessing Progress on Integrating Disaster Risk Reduction and Climate Change Adaptation in Development Processes, Strengthening Climate Resilience Discussion Paper 2, Institute of Development Studies, UK.

Montserrat Ministry of Agriculture, Land, Housing and the Environment (2011): Transforming to a Climate-Resilient and Low Carbon Economy - Montserrat`s Climate Change Policy (Draft). Caribbean Community Climate Change Centre, Belmopan, Belize

Morales Q. and R. Morales. 2006. Regional review on aquaculture development. Latin America and the Caribbean – 2005. FAO Fisheries Circular. No. 1017/1. Rome, FAO. 177 pp.

Norris, N., J. Defoe and M. Ishida. 2011. Ghost Fishing by Lost and Derelict Fish Pots in the Commonwealth of Dominica. Proceedings of the Gulf and Caribbean Fisheries Institute 63:37-40

Nurse, L. 2009. Incorporating Climate Change Projections into Caribbean Fisheries Management. Proceedings of the Gulf and Caribbean Fisheries Institute 61:130-138

Nurse, L. 2011. The implications of global climate change for fisheries management in the Caribbean. Climate and Development 3:228-241

Nurse, L. and R. Moore. 2005. Adaptation to global climate change: an urgent requirement for Small Island Developing States. Review of European Community and International Environmental Law, 14, 100-107.

ODPEM 2011. Rocky Point Community Disaster Risk Management Plan. Office of Disaster Preparedness and Emergency Management, Government of Jamaica.

ODPEM 2012. Old Harbour Bay Community Disaster Risk Management Plan. Office of Disaster Preparedness and Emergency Management, Government of Jamaica.

OECS Secretariat. 2004. Grenada: Macro-Socio-Economic Assessment of the Damages Caused by Hurricane Ivan - September 7, 2004. Organisation of Eastern Caribbean States.

OECS Secretariat. 2005. Macro Socio-Economic Assessment of the Damage Caused by Hurricane Emily. Organisation of Eastern Caribbean States.

OECS Secretariat. 2006. St. George's Declaration of Principles for Environmental Sustainability in the OECS (Revised 2006). OECS Secretariat, Castries

Olhoff, A. and C. Schaer. 2010. Screening Tools and Guidelines to Support the Mainstreaming of Climate Change Adaptation into Development Assistance – A Stocktaking Report. UNDP: New York.

Olsson, P., C. Folke and F. Berkes. 2004. Adaptive co-management for building resilience in social–ecological systems. Environmental Management 34: 75-90.

PAHO. 2000. Fish Mortality in Southeastern Caribbean Countries. Epidemiological Bulletin 8-10.

PIOJ. 2007. Assessment of the socio-economic and environmental impact of Hurricane Dean on Jamaica. Planning Institute of Jamaica. 96pp.

PIOJ. 2008. Assessment of the socio-economic and environmental impact of Tropical Storm Gustav on Jamaica. Planning Institute of Jamaica. 75pp.

Pulwarty, R. and N. Hutchinson. 2008. Vulnerability and capacity assessment methodology: A guidance manual for the conduct and mainstreaming of climate change vulnerability and capacity assessments in the Caribbean. Caribbean Community Climate Change Centre, Belmopan, Belize

Satia, B.P.; Staples, D. (eds.) 2004. Advisory Committee on Fisheries Research. Papers presented at the second session of the Working Party on Small-scale Fisheries. Bangkok, Thailand, 18 – 21 November 2003. FAO Fisheries Report. No. 735, Suppl. Rome, FAO. 198p

Schuhmann, P. W. 2012. The Valuation of marine ecosystem goods and services in the Wider Caribbean Region. CERMES Technical Report No 63. 57 pp

Secretariat of the Convention on Biological Diversity. 2009. Scientific Synthesis of the Impacts of Ocean Acidification on Marine Biodiversity. Montreal, Technical Series No. 46, 61pp

Simpson, M.C. et al. 2010. Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean. United Nations Development Programme (UNDP), Barbados

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) - Turks and Caicos Islands. DFID, AusAID and The CARIBSAVE Partnership, Barbados, West Indies.

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) - Belize. DFID, AusAID and The CARIBSAVE Partnership, Barbados, West Indies.

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) - Jamaica. DFID, AusAID and The CARIBSAVE Partnership, Barbados, West Indies.

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) - Barbados. DFID, AusAID and The CARIBSAVE Partnership, Barbados, West Indies.

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) - Nevis. DFID, AusAID and The CARIBSAVE Partnership, Barbados, West Indies.

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) – St. Kitts. DFID, AusAID and The CARIBSAVE Partnership, Barbados, West Indies.

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) – St Vincent and the Grenadines. DFID, AusAID and The CARIBSAVE Partnership, Barbados, West Indies.

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) – Saint Lucia. DFID, AusAID and The CARIBSAVE Partnership, Barbados, West Indies.

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) - Dominica. DFID, AusAID and the CARIBSAVE Partnership, Barbados, West Indies.

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) - Suriname. DFID, AusAID and the CARIBSAVE Partnership, Barbados, West Indies.

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) – Antigua and Barbuda. DFID, AusAID and the CARIBSAVE Partnership, Barbados, West Indies.

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) - Anguilla. DFID, AusAID and the CARIBSAVE Partnership, Barbados, West Indies.

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) – The Bahamas. DFID, AusAID and the CARIBSAVE Partnership, Barbados, West Indies.

Simpson, M.C. et al. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) - Grenada. DFID, AusAID and the CARIBSAVE Partnership, Barbados, West Indies.

Singh-Renton, S. 2002. The impact of global environmental change on fisheries in the Caribbean – outlining research needs. Submission to Regional GECAFS Preparative Working Group Meeting, 19 - 20 September 2002, CARDI, UWI, St. Augustine.

Spatial Systems Caribbean Ltd. 2006 Disaster Risk Management Benchmarking Tool (B-Tool). Prepared for USAID and OECS.

Suárez. A., E. Garraway. D. Vilamajo, L. Mujica, J. Gerhartz, R. Capote, N. Blake 2008. Climate change impacts on terrestrial biodiversity in the insular Caribbean: Report of Working Group III, Climate Change and Biodiversity in the Insular Caribbean. CANARI Technical Report No.383: 99pp

Taylor, M. 2008. Review of Health Effects of Climate Variability and Climate Change in the Caribbean

Taylor, M. A. et al. 2007. Glimpses of the future: A briefing from the PRECIS Caribbean climate change project, Caribbean Community Climate Change Centre, Belmopan, Belize. 24 pp.

Trotz, U. 2002. Disaster Reduction and Adaptation to Climate Change - A CARICOM Experience. Caribbean Community Climate Change Centre. Belmopan, Belize

Turks and Caicos Islands Climate Change Committee. 2011. Draft Climate Change Policy of the Turks and Caicos Islands. Caribbean Community Climate Change Centre, Belmopan, Belize

Turks and Caicos Islands Climate Change Committee. 2011. Turks and Caicos Islands: Climate Change Green Paper. Caribbean Community Climate Change Centre, Belmopan, Belize

UNDESA. 2012. Climate Change Adaptation in Grenada: Water Resources, Coastal Ecosystems and Renewable Energy. United Nations Department of Economic and Social Affairs

UNDP. 2004. Adaptation Policy Frameworks for Climate Change. Cambridge, UK: Cambridge University Press.

UNDP-UNEP. 2011. Mainstreaming Adaptation to Climate Change into Development Planning: A Guide for Practitioners. UNDP-UNEP Poverty - Environment Initiative. Available from: http://www.unpei.org/knowledge-resources/publications.html

UNEP, FAO, IMO, UNDP, IUCN, World Fish Center, GRIDArendal. 2012. Green Economy in a Blue World. www.unep.org/greeneconomy and www.unep.org/regionalseas

UNEP. 2008. Climate Change in the Caribbean and the Challenge of Adaptation. United Nation Environment Programme Regional Office for Latin America and the Caribbean, Panama City, Panama.

UNISDR 2008. Climate Change and Disaster Risk Reduction, Briefing Note 1. UNISDR, Geneva, Switzerland.

UNISDR 2009. Adaptation to Climate Change by Reducing Disaster Risks: Country Practices and Lessons, Briefing Note 2. Geneva, Switzerland.

UNISDR. 2010. Strengthening climate change adaptation through effective disaster risk reduction. Briefing Note 3. UNISDR. Geneva, Switzerland.

VanAnrooy, R., P.A.D Secretan, Y. Lou, R. Roberts and M. Upar. 2006. Review of the current state of world aquaculture insurance. FAO Fisheries Technical Paper. No. 493. Rome, FAO. 92p.

VanAnrooy, R., I.U. Ahmad, T. Hart, M. Hotta, Y. Ping, W. Yang, T. Shipton, C. Benoit, R. Ruchismita, S. Upare and S.V. Siar. 2009. Review of the current state of world capture fisheries insurance. FAO Fisheries and Aquaculture Technical Paper. No. 510. Rome, FAO. 162p.

WECAFC. 2012. Disaster Risk Management in Fisheries in the WECAFC Region. Background paper for Fourteenth Session of the Western Central Atlantic Fishery Commission (WECAFC), Panama City, Panama, 6 - 9 February 2012.

Westlund, L., F. Poulain, H. Bage, R. van Anrooy. 2007. Disaster response and risk management in the fisheries sector. FAO Fisheries Technical Paper. No. 479. Rome, FAO. 56p.

Zhang, J., J. Fleming and R. Goericke. 2012. Fishermen's perspectives on climate variability. Marine Policy 36: 466–472

7 ANNEXES

7.1 Glossary

Adaptation - The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (UNISDR 2009)

Capacity - The combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals (UNISDR 2009 and IPCC 2012)

Capacity development and capacity building - The process by which people, organizations and society systematically stimulate and develop their capacities over time to achieve social and economic goals, including through improvement of knowledge, skills, systems, and institutions. Capacity development extends the concept of capacity building to encompass all aspects of creating and sustaining capacity growth over time (UNISDR 2009). This distinction is not always made.

Climate change –

(a) The IPCC defines climate change as: "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use".

(b) The UNFCCC defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods"

Climate scenario - A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as about the observed current climate (IPCC 2012).

Climate variability - Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate at all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (IPCC 2012).

Coping capacity and adaptive capacity - The ability of people, organizations and systems, using available skills, resources, and opportunities, to address, manage, and overcome adverse conditions, emergencies or disasters in the short to medium term (UNISDR 2009 and IPCC 2012 slightly modified). Adaptive capacity is exhibited over a longer term and builds resilience.

Disaster - A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources (UNISDR 2009).

Disaster risk management - The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster. This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards (UNISDR 2009) with the explicit purpose of increasing human security, well-being, quality of life, and sustainable development (IPCC 2012).

Disaster risk reduction - The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events (UNISDR 2009).

Downscaling - A method that derives local- to regional-scale (up to 100 km) information from larger-scale models or data analyses (IPCC 2012).

Ecosystem approach to fisheries (EAF) - Strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties of biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries (FAO 2003)

Ecosystem services - The benefits that people and communities obtain from ecosystems (UNISDR 2009)

El Niño-Southern Oscillation (ENSO) - A complex interaction of the tropical Pacific Ocean and the global atmosphere that results in irregularly occurring episodes of changed ocean and weather patterns in many parts of the world, often with significant impacts over many months, such as altered marine habitats, rainfall changes, floods, droughts, and changes in storm patterns (UNISDR 2009).

Emissions scenario – It is a plausible representation of the future development of emissions of substances (e.g., greenhouse gases, aerosols), based on a coherent and internally consistent set of assumptions about driving forces (such as technological change, demographic and socioeconomic development) and their key relationships. Concentration scenarios, derived from emissions scenarios, are used as input to a climate model to compute climate projections. The IPCC Special Report on Emissions Scenarios, the SRES scenarios (e.g. A1B, A1FI, A2, B1, B2), are used for some climate projections (IPCC 2012 summarised).

Exposure - People; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected (IPCC 2012).

Governance - Governance is public and private interactions initiated to solve societal problems and create societal opportunities. It includes the principles guiding these interactions and the institutions that enable them. (Kooiman et al 2005)

Greenhouse gases - Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds (UNISDR 2009)

Hazard - A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (UNISDR 2009).

Likelihood - A probabilistic estimate of the occurrence of a single event or of an outcome, for example, a climate parameter, observed trend, or projected change lying in a given range. Likelihood may be based on statistical or modelling analyses, elicitation of expert views, or other quantitative analyses (IPCC 2012).

Livelihood - the capacity, assets (including both material and social resources) and activities required to earn an income or acquire resources that can be used or exchanged to satisfy the needs of an individual, family or social group (Bell et al 2011).

Mainstreaming - Making a concept or practice an integral dimension of the policies, plans and programmes in all political, economic and societal spheres down to operational level (CDERA 2007 modified)

Mitigation (of disaster risk and disaster) **-** The lessening of the potential adverse impacts of natural hazards, environmental degradation and technological hazards through structural and non-structural measures that reduce hazard, exposure, and vulnerability (UNISDR 2009 modified and IPCC 2012).

Mitigation (of climate change) - A human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC 2012).

Ocean acidification - A decrease in the pH of sea water due to the uptake of anthropogenic carbon dioxide (IPCC 2007).

Preparedness - The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions (UNISDR 2009).

Prevention - Activities to provide outright avoidance of the adverse impact of hazards and disasters. Depending on social and technical feasibility and cost/benefit considerations, investing in preventive measures is justified in areas frequently affected by disasters. In the context of public awareness and education, related to disaster risk reduction changing attitudes and behaviour contribute to promoting a "culture of prevention" (CDERA 2007 modified).

Recovery - Restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors (UNISDR 2009).

Response - The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected (UNISDR 2009).

Resilience - The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions (IPCC 2012)

Risk - The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions. Conventionally risk is expressed by the notation Risk = Hazards x Vulnerability. Some disciplines also include the concept of exposure to refer particularly to the physical aspects of vulnerability. Beyond expressing a possibility of physical harm, it is crucial to recognize that risks are inherent or can be created or exist within social systems. It is important to consider the social contexts in which risks occur and that people therefore do not necessarily share the same perceptions of risk and their underlying causes. (CDERA 2007).

Risk assessment - A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend (UNISDR 2009).

Risk management - The systematic approach and practice of managing uncertainty to minimize potential harm and loss. (UNISDR 2009)

Sea level change - Changes in sea level, globally or locally, due to (i) changes in the shape of the ocean basins, (ii) changes in the total mass and distribution of water and land ice, (iii) changes in water density, and (iv) changes in ocean circulation (IPCC 2012)

Social-ecological system – reflects the perspective that social systems and ecological systems are inevitably linked and integrated, and that any delineation between the two systems is artificial and arbitrary (Berkes and Folke 1998)

Transformation - The altering of fundamental attributes of a system (including value systems; regulatory, legislative, or bureaucratic regimes; financial institutions; and technological or biological systems) (IPCC 2012)

Uncertainty - An expression of the degree to which a value or relationship is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. Uncertainty may originate from many sources, such as quantifiable errors in the data, ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures, for example, a range of values calculated by various models, or by qualitative statements, for example, reflecting the judgment of a team of experts (IPCC 2012).

Vulnerability - The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard (UNISDR 2009)

7.2 Participants in the four country consultations

Grenada	
Coddinton Jeffrey	MBMPA, Fisheries Division
Dianne John	Southern Fishermen Association
James Ince	Spice Isle Fishhouse
Paul Phillip	Environmental Unit
Roland Baldeo	Fisheries Division
Samantha Wellington	Southern Fishermen Association
Sandra Ferguson	Agency for Rural Transformation Ltd.
Terrence Walters	National Disaster Management Agency (NaDMA)
Terry Charles	Grenada Red Cross Society
Timothy Scott	National Telecommunications Regulatory Commission
Guyana	
Arnold DeMendoza	IICA
B Samwaree	Sams Local Seafood
Bissessar Chintamanie	Guyana School of Agriculture (GSA)
De Vaughn Lewis	Guyana Red Cross
Denzil Roberts	Fisheries Department
Gary Baird	Fisheries Department
Geeta Devi Singh	Environmental Protection Agency
George Jervis	PS, Ministry of Agriculture
Hon Dr. Leslie Ramsammy	Minister of Agriculture
Kandila Ramotar	Office of Climate Change
Kester Craig	Civil Defense Commission
Lili Ilivea	Conservation International
Lystra Fletcher-Paul	FAO
Monique Williams	Environmental Protection Agency
Nasheta Dewnath	Guyana Forestry Commission
Omadoff Chandan	NDIA
Raquel Thomas-Caesar	Iwokrama
Reuben Charles	GATOSP = trawler association
Jamaica	
Abigail McIntosh	Environmental Solutions Ltd
Ainsworth Riley	Inter-American Institute for Cooperation on Agriculture (IICA)
Andre Kong	Fisheries Division
Anthony Drysdale	Jamaica Fishermen's Cooperative Union
Arpita Mandal	UWI Dept. of Geography and Geology
Avery Smikle	Fisheries Division
Barbara Carby	DRR Centre, UWI Mona
Camilo Trench	Discovery Bay Marine Laboratory
Christopher Brown	Half Moon Bay Fishermen's Cooperative
Clifford Mahlung	Meteorological Services of Jamaica
Clive Williams	Fisheries Division
Dale Rankine	Dept of Physics, UWI, Mona
Donna Blake	The Nature Conservancy

Farrah Hansel	Fisheries Division
Gabrielle Watson	NEPA Climate Change Adaptation Project
Georgia Marks-Doman	Ministry of Agriculture and Fisheries
Hyacinth Douglas	Global Environment Facility Small Grants Programme (GEF SGP)
Ian Jones	Fisheries Division
Ingrid Parchment	Caribbean Coastal Area Management Foundation
Jayaka Campbell	Dept of Physics, UWI, Mona
Junior McDonald	Fisherman
Karema Aikens Mitchell	Office of Disaster Preparedness and Emergency Management (ODPEM)
Karen McDonald Gayle	Environmental Foundation of Jamaica
Karl Aiken	Dept of Life Sciences, UWI, Mona
Malden Miller	OSD/USAID Jamaica
Marc Panton	Ministry of Agriculture and Fisheries
Margaret Jones-Williams	United Nations Development Programme
Maureen Milbourn	NEPA
Michael R A Wilson	Water Resources Authority
Michelle McNaught	CARIBSAVE Partnership
Susan Otuokon	Independent Consultant
Nakhle Hado	Food for the Poor
NaSumma Davis	Ministry of Agriculture and Fisheries
Nicholette Williams	Ministry of Foreign Affairs and Foreign Trade
Orville Grey	The Nature Conservancy
Paul Armstrong	Greenwich Town Fisheries
Paula Sterling	Aquaculturist
Phillip Chung	Rural Agricultural Development Authority
Ricardo Morris	Fisheries Division
Richard Kelly	Planning Institute of Jamaica
Robin Hall	Ornamental fish farmer
Selena Legister-Kellier	Food for the Poor
Sydney Francis	Ton-Rick Enterprise Ltd
Ta'Chala Beecher	Fisheries Division
Vincent Wright	Aquaculturist
Belize	
Beverly Wade	Fisheries Department
Rigoberto Quintana	Fisheries Department
Vivian Belisle	Fisheries Department
Ramon Carcamo	Fisheries Department
Fred Hunter	Belize Red Cross
Llewellyn Smith	Belize Fishermen Federation
Pedro Alvarez	Belize Fishermen Cooperative Association
Vincent Gillett	CZMAI
Colin Gillett	CZMAI
Amanda Burgos-Acosta	Belize Audubon Society
Shane Young	Belize Audubon Society
Ramon Pachero	Programme for Belize
Janet Gibson	Wildlife Conservation Society

Roberto Pott	Healthy Reefs
Losita Lee	Association of Protected Areas Management Organizations (APAMO)
Nadia Bood	World Wildlife Fund
Wendell Parham	Ministry of Forestry, Fisheries and Sustainable Development
Keith Nichols	CCCCC
Keith Emmanuel	National Emergency Management Organization (NEMO)
Celso Cawich	Environmental Research Institute- University of Belize

7.3 Extract from summary of physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture

❖ **PHYSICAL IMPACTS ON MARINE AND FRESHWATER SYSTEMS**

➢ **Heat content and temperature**

- Ocean warming shows geographic differences and decadal variability
- Warming is not only of surface waters; the Atlantic shows clear signs of deep warming
- Freshwater resources are vulnerable; many lakes have experienced warming
- Lake water levels (which affect temperature impacts) have been decreasing in many areas, mostly as a result of human use, but precipitation patterns are also important
- River run-off may increase at higher latitudes and decrease in southern Latin America

➢ **Salinity and stratification**

- In general, salinity is increasing in surface ocean waters of the more evaporative regions, while there is a decreasing trend in high latitudes
- The combined effect of temperature and salinity changes would reduce the density of the surface ocean, increase vertical stratification and change surface mixing, but with some geographical differences

➢ **Ocean circulation and coastal upwelling**

- Low-resolution ecosystem simulations indicate that there is no clearly discernible pattern of upwelling response to warming at the global scale, except within a couple of degrees of the equator, where a small reduction is expected.
- There are indications that upwelling seasonality may be affected by climate change, with important food web consequences.
- Responses to global warming of coastal wind systems that drive upwelling ecosystem are contradictory.
- If alongshore wind stress increases coastal upwelling, this would offset in these regions the global trend of increasing water temperatures and increasing vertical stratification, but some models predict decrease in winds favourable to upwelling
- There is considerable local variability among systems which makes generalizations difficult.

➢ **Sea level rise**

- Global average sea level has been rising at an average rate of 1.8 mm per year since 1961. The rate has accelerated since 1993 to about 3.1 mm per year. Higher rates in coming decades are likely. Sea level change is not geographically uniform, however, because it is controlled by regional ocean circulation processes
- The largest losses expected from sea level rise are likely to include the Atlantic and Gulf of Mexico coasts of the Americas, the Mediterranean and small-island regions.
- Intertidal and coastal wetland habitats may be substantially reduced as a result of sea level rise.

➢ **Acidification and other chemical properties**

- Surface seawater pH has decreased by 0.1 units in the last 200 years. Model estimates predict further reduction of 0.3 to 0.5 pH units over the next 100 years.
- Biological impacts of ocean acidification are uncertain because sensitivities at individual and population level are unknown. However, they are expected to be severe for shell-borne organisms, tropical coral reefs and cold water corals.
- The oxygen concentration of the ventilated 100 to 1000 m of the world's ocean has

been decreasing since 1970, driven by a reduced rate of renewal of intermediate waters.

- Global warming is likely to decrease nutrient supply to surface waters due to increased stratification.

➢ **Atmosphere-ocean and land-oceans exchanges**

- Land-use change has significant hydrological impacts with consequences for ecosystem production, including changes in sediment loads, water flows (through damming) and physico-chemical consequences (hypoxia, stratification and salinity changes). The consequences of these processes cannot be generalized. However, they are known to impact community composition, production and seasonality processes in plankton and fish populations.
- The above will put additional pressure on inland fish and land-based, water intensive, food production systems (e.g. rice), particularly in developing countries.

➢ **Low frequency climate variability patterns**

- Some studies indicate an increase in the intensity and frequency of particular atmospheric patterns (e.g. ENSO), but in general climate models predict a rather spatially uniform warming trend throughout the ocean basins combined with the continued presence of decadal variability similar to that of the twentieth century.
- Atmospheric patterns can have strong tele-connections within individual ocean basins, but between-basin tele-connections and potential climate-driven biological synchrony over several decades, are usually much weaker.

❖ **OBSERVED EFFECTS OF CLIMATE VARIABILITY AND CHANGE ON ECOSYSTEM AND FISH PRODUCTION PROCESSES**

➢ **Primary production**

- Satellite observations suggest a 6 percent reduction in global oceanic primary production between the early 1980s and the late 1990s, but with substantial regional differences. Chlorophyll in higher latitudes has increased in the last 20 years, followed by a change in the relative dominance of diatoms over small phytoplankton.
- Increased vertical stratification and water column stability in oceans and lakes is likely to reduce nutrient availability to the euphotic zone and thus primary and secondary production in a warmed world. However, in high latitudes the residence time of particles in the euphotic zone will increase, extending the growing season and thus may increase primary production. Overall, a small global increase in primary production will be expected, with very large regional differences.
- The onset of the diatom spring bloom could be delayed and its peak biomass reduced. Changes in the dominant phytoplankton group appear possible.
- The intensification of hydrological cycles is expected to influence substantially limnological processes. In general, increased run-off, discharge rates, flooding area and dry season water level may boost productivity at all levels (plankton to fish). Changes in the timing of floods may trigger production at the wrong time and flush biological production out of its habitat.

➢ **Secondary production**

- There are no global assessments of the potential impacts of climate change on oceanic secondary production. Results tend to be dominated by local or regional conditions
- Regional results suggest that climate change effects may be more evident in the structure of zooplankton communities than in its total biomass.

- **Distributional changes**
  - Climate change is expected to drive most terrestrial and marine species ranges toward the poles, expanding the range of warmer-water species and contracting that of colder-water species.
  - Observations of distributional changes consistent with the above have been recorded for copepods, demersal invertebrates, intertidal organisms and fish species. The most rapid changes in fish communities occur with pelagic species, and include vertical movements to counteract surface warming.
  - Timing of many animal migrations follows decadal trends in ocean temperature, being later in cool decades and up to one to two months earlier in warm years.

- **Abundance changes**
  - Populations at the poleward extents of their ranges tend to increase in abundance with warmer temperatures, whereas populations in more equatorward parts of their range tend to decline in abundance as temperatures warm.
  - Increased growth rates in response to increased temperatures are only achieved when food supply is adequate to these increased demands.

- **Life cycle changes**
  - More than half of all terrestrial, freshwater or marine species studied have exhibited measurable changes in their phenologies over the past 20 to 140 years. These were systematically and predominantly in the direction expected from regional changes in the climate.
  - Observations in the North Sea indicate that plankton community structure is changing: dinoflagellates have advanced their seasonal peak in response to warming, while diatoms have shown no consistent pattern of change because their reproduction is triggered principally by increases in light intensity.
  - Observations in many European and North American lakes suggest that the spring phytoplankton bloom has advanced due to warming but that zooplankton has not responded similarly, and their populations are declining because their emergence no longer corresponds with high algal abundance. There is concern that marine and freshwater trophodynamics may have already been radically altered by ocean warming through predator-prey mismatch.

- **Species invasions and diseases**
  - There is little evidence in support of an increase in outbreaks of disease linked to global warming, although spread of pathogens to higher latitudes has been observed.
  - Harmful algal blooms seem to be more common, but whether this is caused by climate change is unclear. The expected change in the ratio of diatoms to dinoflagellates in a warming ocean may also play a role.
  - Extinction risks due to climate change are possible, but there are no known examples yet. Evolutionary adaptations will occur, although on time scales and with characteristics that may be species-dependent.

- **Food web impacts from zooplankton to fish**
  - Climate change is likely to affect ecosystems and their species both directly and indirectly through food web processes. Whether direct or indirect processes predominate is likely to depend on whether they are structured from the top down, from the bottom up or from the middle. It is suggested that ecosystem control is correlated with species richness and temperature.

- **Regime shifts and other extreme ecosystem events**
  - One of the mechanisms through which climate variability and change interact in

affecting ecosystem dynamics is through non- linear "regime shifts". The sensitivity of ecosystems to amplify climatic signals suggests that gradual (or even stochastic) changes in climate can provoke sudden and perhaps unpredictable biological responses as ecosystems shift from one state to another.

- Regime shifts have been observed in the North Atlantic and North Pacific oceans, among others, affecting productivity and species dominance in the pelagic and demersal domains.

❖ **SCENARIOS OF CLIMATE CHANGE IMPACTS ON FISH PRODUCTION AND ECOSYSTEMS**

➢ **General impacts**

- Impacts on marine and aquatic systems as a result of large-scale changes related to temperature, winds and acidification can be predicted, in some cases with a high degree of confidence.
- At "rapid" time scales (a few years) there is high confidence that increasing temperatures will have negative impacts on the physiology of fish because of limited oxygen transport to tissues at higher temperatures. This physiological constraint is likely to cause significant limitations for aquaculture. These constraints on physiology will result in changes in distributions of both freshwater and marine species, and likely cause changes in abundance as recruitment processes are impacted. Changes in the timing of life history events are expected with climate change (high confidence). Short life span, rapid turnover species, for example plankton, squid and small pelagic fishes, are those most likely to experience such changes.
- At intermediate time scales (a few years to a decade), temperature-mediated physiological stresses and phenology changes will impact the recruitment success and therefore the abundances of many marine and aquatic populations (high confidence). These impacts are also likely to be most acute at the extremes of species' ranges and for shorter-lived species. Changes in abundance will alter the composition of marine and aquatic communities, with possible consequences for the structure and productivity of these marine ecosystems. Predicting net community impacts (e.g. total biomass or productivity) has intermediate confidence because of compensatory dynamics within functional groups. Increasing vertical stratification is predicted for many areas, and is expected to reduce vertical mixing and decrease productivity (intermediate confidence). It will drive changes in species composition.
- At long time scales (multidecadal), predicted impacts depend upon changes in net primary production in the oceans and its transfer to higher trophic levels. Models show high variability in their outcomes so any predictions have low confidence. Regional predictions may have improved confidence because of better knowledge of the specific processes involved. Most models show decreasing primary production with changes of phytoplankton composition to smaller forms, although with high regional variability.
- Considerable uncertainties and research gaps remain, in particular the effects of synergistic interactions among stressors, extrapolating beyond historical conditions, reduced ecosystem resilience to climate variability as a result of changes caused by fishing, the locations and roles of critical thresholds and the abilities of marine and aquatic organisms to adapt and evolve to the changes.
- Regarding freshwater systems, there are specific concerns over changes in timing, intensity and duration of floods, to which many fish species are adapted in terms of migration, spawning and transport of spawning products as a result of climate change. It is important to develop management systems capable of addressing the

needs for fresh water by fish and land-based food production systems (e.g. rice) in the context of climate change, particularly in developing countries.

- **Aspects of responses in tropical and subtropical seas include:**
  - highly diverse habitats and biology; poorly studied;
  - not fully resolved whether tropical Pacific will become more "El Niño-like" (east-west gradient in SST is reduced), or more "La Niña-like" character (increased east-west SST gradient);
  - primary production in the tropical Pacific expected to decline because of increased stratification and decreased nutrient supply;
  - combined effects of changes in circulation, temperature, nutrients, primary production cascade up the food web to influence prey availability and habitat conditions for tuna;
  - tuna habitat conditions east of the date line could improve, similar to El Niño-events;
  - warming and increasing stratification will alter plankton community composition, alter their distributions polewards and change the timing of their bloom dynamics so that transfers to higher trophic levels may be impaired;
  - benthic and demersal fishes will shift their distributions southward and may decline in abundance. Pelagic species will also shift their distributions southwards and some species may benefit from increased local wind-driven upwelling (e.g. anchovies).

- **Aspects of responses in coral reef systems include:**
  - at risk from climate change impacts related to increasing temperatures, acidity, storm intensity and sea levels and non-climate factors such as overexploitation, non-native species introductions and increasing nutrient and sediment loads;
  - risks to coral reefs not distributed equally: increasing temperatures significant issue for warm-water systems; increasing acidity and decalcification a significant issue for both warm- and cold-water systems; direct human impacts a significant issue in more populous regions;
  - three different time scales can be identified for climate change-related impacts to coral reef systems:
    - years: increased temperature effects on coral bleaching;
    - decades: increasing acidification and dissolution of carbonate structures of reefs;
    - multidecades: weakening of structural integrity of reefs and increasing susceptibility to storms and erosion events.
  - increasing acidity (decreasing pH) is a significant and pervasive longer-term threat to coral reefs. Potential for coral reef systems to adapt to these environmental stresses is uncertain: symbiotic zooxanthellae may adapt to be more tolerant of high temperature. Migrations of corals to higher latitudes is unlikely;
  - declines in corals had negative impacts on reef fish biodiversity in at least one study, however, to date there is little evidence for a link between climate warming and bleaching events with impacts on coastal fisheries.

- **Aspects of responses in freshwater systems include:**
  - freshwater lakes and their ecosystems are highly vulnerable to climate change;
  - paleo records show the shapes and distributions of lakes can change and they can disappear entirely with shifting dynamics among precipitation, evaporation and runoff;
  - anticipated response is for cold-water species to be negatively affected, warm-water species to be positively affected and cool-water species to be positively affected in

the northern, but negatively affected in the southern parts of their range;

- general shift of cool- and warm-water species northward is expected in North America and likely the rest of the Northern Hemisphere;
- responses of particular lake ecosystems to climate change depend on size, depth and trophic status of the lake;
- v modelling studies concluded cold-water fish would be most affected because of losses of optimal habitats in shallow, eutrophic lakes;
- growth conditions for cool- and warm-water fishes should improve in well-mixed lakes, small lakes and those with oligotrophic nutrient conditions;
- rates of change of freshwater systems to climate will depend on ability of freshwater species to "move across the landscape", i.e. use of dispersal corridors;
- most affected are likely to be fish in lowland areas that lack northward dispersal corridors, and cold-water species generally;
- river ecosystems are particularly sensitive to changes in the quantity and timing of water flows, which are likely to change with climate change;
- changes in river flows may be exacerbated by human efforts to retain water in reservoirs and irrigation channels;
- abundance and species diversity of riverine fishes are particularly sensitive to these disturbances, since lower dry season water levels reduce the number of individuals able to spawn successfully and many fish species are adapted to spawn in synchrony with the flood pulse to enable their eggs and larvae to be transported to nursery areas on floodplains.

➢ **Aspects of responses in aquaculture systems include:**

- direct impacts include changes in the availability of freshwater, changes in temperature, changes in sea level, and increased frequencies of extreme events (such as flooding and storm surges);
- indirect effects include economic impacts, e.g. costs and availability of feed;
- negative impacts include:
  - stress due to increased temperature and oxygen demands;
  - uncertain supplies of freshwater;
  - extreme weather events;
  - sea level rise;
  - increased frequency of diseases and toxic events;
  - uncertain supplies of fishmeal from capture fisheries.
- positive impacts of climate change on aquaculture include increased food conversion efficiencies and growth rates in warmer waters, increased length of the growing season, and range expansions polewards due to decreases in ice;
- increased primary production would provide more food for filter-feeding invertebrates;
- may be problems with non-native species invasions, declining oxygen concentrations, and possibly increased blooms of harmful algae;
- local conditions in traditional rearing areas may become unsuitable for many traditional species;
- temperature stress will affect physiological processes such as oxygen demands and food requirements;
- increased food supplies are needed for aquaculture activities to realise benefits from increased temperatures;
- freshwater aquaculture activities will compete with changes in availability of freshwater due to agricultural, industrial, domestic and riverine requirements, as well as changes in precipitation regimes;
- increases in precipitation could also cause problems such as flooding;
- sea level rise also has the potential to flood coastal land areas, mangrove and sea

grass regions which may supply seed stock for aquaculture species.

Source:

Barange, M. and R.I. Perry. 2009. Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture. Pp. 7–106 in K. Cochrane, C. De Young, D. Soto and T. Bahri (eds). Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO