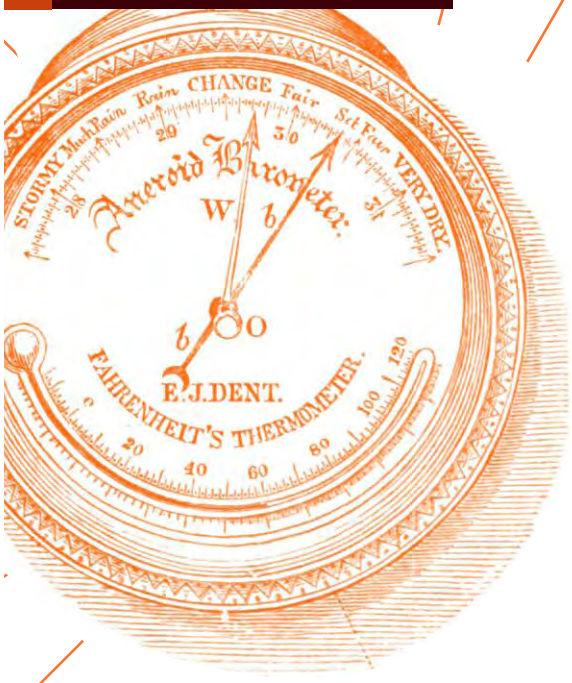
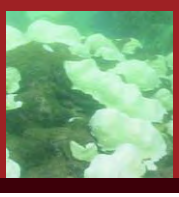
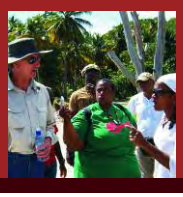
Climate Change and Disaster Risk Reduction

Caribbean Natural Resources Institute

Technical Report No. 386



The impacts of climate change on biodiversity in Caribbean islands: what we know, what we need to know, and building capacity for effective adaptation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This document was written by Dr Owen Day and is based on the work carried out over two years by the project steering committee, chaired by Professor John Agard and three specialist working groups, led by Professor Anthony Chen, Dr Gillian Cambers and Professor Avelino Suarez (see page 8 for full details). Thanks are also due to all those who commented on the first drafts of the Working Group reports.

Acronyms

CANARI	Caribbean Natural Resources Institute
CARICOM	Caribbean Community
CBD	Convention on Biodiversity
CCBIC	Climate Change and Biodiversity in the Insular Caribbean
CCCCC	Caribbean Community Climate Change Centre
CIMH	Caribbean Institute for Meteorology & Hydrology
CSGM	Climate Studies Group Mona
INSMET	The Instituto de Meteorologia, Cuba
IPCC	Intergovernmental Panel on Climate Change
MMD	model data set
MPA	Marine Protected Area
PA	Protected Area
PCMDI	Program for Climate Model Diagnosis and Inter-comparison
SPAW	Specially Protected Areas and Wildlife
UNEP	United Nations Environment Programme
WG	Working Group

Executive Summary

Climate change is one of the most critical issues facing the world today and likely to cause massive and potentially irreversible damage to the global environment and human society. The need for urgent action to combat climate change and reduce emissions of greenhouse gases is now recognised by all nations as a top international priority. For small developing countries the priority must be on formulating appropriate strategies for adaptation. This is particularly true for small island states, such as those of the Caribbean, which the Intergovernmental Panel on Climate Change (IPCC) considers to be among the most vulnerable to the projected impacts of climate change, such as rising sea levels, intensifying storms, mass coral bleaching events and potential water and food shortages.

The process of developing effective adaptation strategies is complex and requires a good understanding of both the potential hazards and vulnerabilities. The Caribbean's reliance on natural resources and ecosystem services (e.g. forests for clean water supplies and micro-climate regulation, coral reefs for coastal protection) makes the region particularly vulnerable to environmental perturbations. And the threats from climate change cannot be viewed in isolation, but rather within the context of existing environmental pressures, such as habitat loss, deforestation, soil erosion, coastal pollution and over-fishing. The cumulative and compounding impacts of climate change are now pushing many ecosystems to the point of collapse (e.g. coral reefs) or lowering their ability to recover from diseases, pests or invasive species. While the linkages between biodiversity, human well-being and economic activities, such as tourism, agriculture and fisheries, have been recognised by scientists for many years, they have often not been reflected in policy. The need for a closer and more informed dialogue between scientists and policy-makers on adaptation is now more urgent than ever.

This document summarises the findings of a project, Climate Change and Biodiversity in the Insular Caribbean, implemented by CANARI under funding from the John D, and Catherine T. MacArthur Foundation (MacArthur). The aim of this project was to increase the understanding and consensus on what is known, and perhaps more importantly on what is not known, about the predicted climate change trends and their impact on biodiversity in the Caribbean. The specific goals were to develop a regional research agenda, to assess the requirements for addressing identified knowledge gaps, and to consider how protected area management, biodiversity protection, and conservation policy might address climate change in the region.

The findings of the project have highlighted a range of challenges and opportunities. In particular there is a need to establish more effective regional mechanisms for the digitisation and sharing of existing data, as well as for the coordination of data collection programmes. Existing climate models need to be downscaled and refined through multidisciplinary research, and supported with training and international collaboration. Reliable computer models, which are essential for good policy-making, need to be expanded to examine the impacts of climate change on biodiversity, agriculture and fisheries.

Multidisciplinary research is also needed for the development of more effective conservation strategies. Networks of protected areas (PAs) are seen as critically important to the conservation of biodiversity, but their management is often inadequate or non-existent. Creating successful PAs will require the input of ecologists, social scientists and economists in order to develop effective management regimes and secure the input and support of local communities. The burgeoning field of environmental economics is developing rigorous methodologies that offer new insights and guidance to policy-makers.

Perhaps most importantly, the project has highlighted the need for more effective communication between scientists, policy-makers and communities. Greater public awareness and understanding is required to provide Caribbean communities with the knowledge, tools and skills to effectively adapt to climate change.

1. Context

Climate change is one of the most critical issues facing the world today and could potentially cause massive and irreversible damage to the global environment and human society. The scientific consensus from the Intergovernmental Panel on Climate Change (IPCC) is that global warming is set to continue in the coming decades with a high probability that the rate of change will accelerate due to positive feedback mechanisms in the earth's biological and physical systems. The need for urgent action to combat climate change and reduce emissions of greenhouse gases is now recognised by all nations as a top international priority.

Climate change and climate variability.

While climate change is a global issue that requires coordinated action by all nations, the bulk of the responsibility for climate change mitigation rests in the hands of the more industrialised countries whose carbon emissions make up the large majority of the global output. For small developing countries, such as those of the Caribbean, the main priority is to implement appropriate adaptation strategies that minimise the social and environmental impacts of climate change. Effective adaptation strategies require an in-depth understanding of the impacts and a detailed assessment of vulnerability.

The Caribbean's heavy reliance on natural resources and ecosystem services makes biodiversity conservation a critical issue for human well-being. It is a region of unusually high biological diversity, hosting as endemics 2.3% of the world's known vascular plant species and 2.9% of the world's endemic vertebrate species, while occupying only 0.15% of the Earth's surface. It has been estimated that the rich flora of the Caribbean region comprises 7000 endemic species. These attributes have prompted Conservation International to designate the Caribbean among the top eight of the world's 25 biodiversity "hotspots" (Conservation International 2007).

According to the IPCC, the Caribbean region is considered to be particularly vulnerable to the numerous and varied impacts of human induced climate change.

Climate change can be seen as a trend in one or more climatic variables characterised by a fairly smooth continuous increase or decrease of the average value during the period of record (at least 30 years). The United Nations Framework Convention on Climate Change (UNFCCC) makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. The El Niño/La Niña variation is an example of climate variability due to natural causes.

These include sea level rise, increasing mean temperatures, changes in seasonal rainfall patterns and increasing frequency of extreme weather events (see Section 3.1). The escalating intensity of hurricanes, in particular the increased number of category 3 and higher hurricanes since 1995, is a particularly serious concern for many Caribbean islands. The impact of the four consecutive tropical storms/ hurricanes that affected Haiti and Cuba in 2008 demonstrated the region's existing vulnerability to weather-related hazards and also highlighted the importance of planning and adaptation. The striking difference in the scale of the human loss and damage to infrastructure in these two countries reflects Cuba's more extensive adaptation planning and forest conservation measures. Mass coral bleaching events have also become more frequent and more severe in recent years, in particular the widespread and catastrophic bleaching event of 2005 in the Caribbean. This is presenting a new challenge to islands dependent on reefs for fisheries, dive tourism and coastal protection. Climate

change and variability are also affecting the region's food security, with failing crops and shifting populations of commercially important species of fish exacerbating the trend of reduced agricultural production.

The threats from climate change must not be viewed in isolation, but rather within the context of the existing environmental pressures that affect most Caribbean islands, such as habitat loss, deforestation, soil erosion, pollution and over-fishing. In the last three decades, the rapid pace of tourism development, urbanisation and population growth throughout the Caribbean, has presented major challenges to policy-makers, planners and environmental managers. The new and emerging threats from climate change make the challenge even more daunting.

The responsibility of research scientists to provide accurate and relevant information is perhaps greater than ever. The international nature of climate change and adaptation research, however, also presents opportunities for collaboration and assistance. The region is not alone in needing to address specific knowledge and research gaps, as well as national and regional institutional weaknesses. Opportunities for greater regional collaboration are being promoted politically, and could be facilitated by new sources of international financial assistance. The Caribbean's research community needs to enhance the mechanisms for regional collaboration and coordination, opening channels for complementary expertise and research synergies. Climate change adaptation is also an opportunity to access new sources of technical support and technologies that could greatly facilitate the many aspects of environmental management, including data-sharing, analysis, communication, public outreach, monitoring and enforcement.

2. Project Background

2.1 Overview

To address the need for a better understanding of vulnerability, the John D. and Catherine T. MacArthur Foundation launched in March 2007 the Climate Change and Biodiversity in the Caribbean (CCBIC) Project, with the Caribbean Natural Resources Institute (CANARI) selected as the implementing agency. The project focused on increasing understanding and consensus on what is known, and perhaps more importantly what is not known, about the predicted climate change trends and their impact on biodiversity in Caribbean Small Island Developing States (SIDS). The goal was to develop a regional research agenda and capacity needs assessment to address identified knowledge gaps and to consider how protected area management, biodiversity protection, and conservation policy might address climate change in the region over the next decade.

The CCBIC project forms part of Phase 1 of MacArthur's interim strategy for climate change (2006-2010), with similar assessments taking place on a phased basis in:

- Eastern Himalaya
- Lower Mekong
- Melanesia
- Madagascar
- Albertine Rift
- Northern Andes
- Southern Andes

At the World Conservation Congress in Barcelona in October 2008, MacArthur organised a one-day workshop to compare the initial findings and methods used by these regional assessments. The meeting also served to facilitate communication across the broader conservation community on the issue of climate change and adaptation, with a view to sharing lessons and catalysing partnerships.

Once Phase 1 is complete, MacArthur's interim strategy will focus on grant making to respond to the recommendations of the assessments and to mainstream climate change adaptation into all its conservation work. The interim strategy findings and outcomes will then be factored into a comprehensive planning process to define MacArthur conservation grant making after 2010 which might result in changes such as a shift in geographic priorities, increased investment in areas that are especially resilient and which might qualify as 'Noah's Parks'.

2.2 Methodology

The approach taken by CANARI was to establish a multi-disciplinary Steering Committee, which met for the first time in March 2007 in Port of Spain, Trinidad. This resulted in the establishment of three Working Groups (WG) of experts (see Diagram 1) from across the Caribbean region with specialist knowledge the following three fields:

- Working Group 1 - Climate change scenarios and models
- Working Group 2 - Impacts of climate change on coastal and marine biodiversity
- Working Group 3 - Impacts of climate change on terrestrial biodiversity

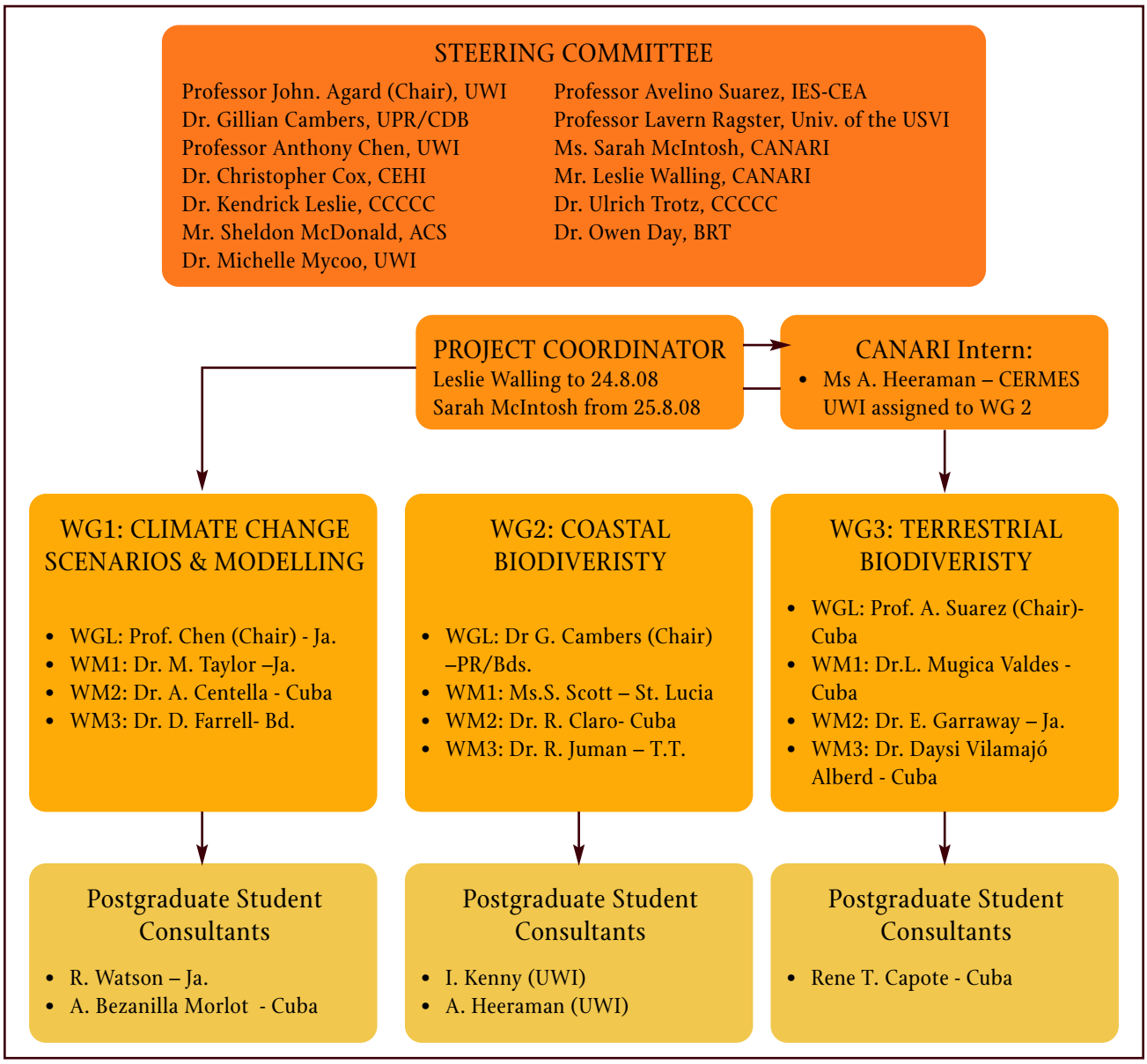
The groups sought to analyse data (whether in English, French or Spanish) from the independent island countries and dependent territories in the Caribbean. The primary language of the project meetings and working group reports was English, but the key outputs (this summary and a policy brief) are also available in Spanish and French.

In June 2007, the three working groups were assigned the task of assessing the state of knowledge about the expected impacts of global climate change in their respective fields, identifying gaps in the knowledge base and proposing relevant research to fill these gaps. Between June and August 2007, literature surveys were conducted by postgraduate students from the University of the West Indies. In August-September 2007, the working groups met in Kingston, Jamaica, where the report outlines were prepared and the specific tasks divided between working group members.

The second meeting of the Steering Committee was held in Kingston, Jamaica in February 2008. The working group leaders presented progress reports and their interim findings. In July 2008, the detailed reports from each working group were sent to CANARI and then circulated amongst regional scientists for review and comment. The comments were collated and the reports synthesised for any cross-cutting issues and/or research synergies.

Diagram 1: Project coordination

The coordination and various components of the CCBIC project are shown in following diagram:



Country Abbreviations

Bd.: Barbados
Ja.: Jamaica
P.R.: Puerto Rico
TT: Trinidad and Tobago

Project Abbreviations

WG: Working Group
WGL: Working Group Leader
WGM: Working Group Member

Institutional Abbreviations

ACS: Association of Caribbean States
BRT: Buccoo Reef Trust
CCCCC: Caribbean Community Climate Change Centre
CDB: Caribbean Development Bank
CEHI: Caribbean Environmental Health Institute
CERMES: Centre for Resource Management and Environmental Studies
IES-CEA: Institute of Ecology and Systematic, Cuban Environmental Agency
Agencia de Medio Ambiente Cuba
UPR: University of Puerto Rico
USVI: United States Virgin Islands
UWI: University of the West Indies

The reports, comments and analysis were then presented at a regional meeting in Port-of-Spain, Trinidad, on the 24th and 25th September 2008. This meeting brought together the Steering Committee, working group leaders, regional and national policy makers and specialists from diverse fields, including communications and advocacy. Participants discussed, analysed and prioritised the research agendas and capacity needs identified in the working group reports. The outputs from that workshop include this document, a policy brief entitled Climate change in the Caribbean: the case for greater investment in research and adaptive policies.and the final detailed reports from the three working groups. All these documents are available on the CANARI website at http://www.canari.org/macarthurclimatechange.html.

3. Status of Research

3.1 Climate change scenarios and models (Working Group I)

Research on climate variability and climate change in the Caribbean focuses on understanding the observed changes in key climatic variables such as daily and seasonal precipitation, temperature, relative humidity, evaporation rates, sea-level rise and changes in the characteristics of extreme events. It also plays a critical role in informing the development and implementation of adaptation strategies to mitigate the impact of climate change on socio-economic development at the local, national, and regional levels. Information from these studies is expected to inform local, national, and regional policies related to sustainable development.

The Caribbean Community Climate Change Centre (CCCCC) coordinates much of the Caribbean region's response to climate change. Officially opened in August 2005, the Centre is a key node for information on climate change issues and on the region's response to managing and adapting to climate change in the Caribbean. It is the official repository and clearing house for regional climate change data, providing climate change-related policy advice and guidelines to the Caribbean Community (CARICOM) Member States through the CARICOM Secretariat. In this role, the Centre is recognised by the United Nations Framework Convention on Climate Change, the United Nations Environment Programme (UNEP), and other international agencies as the focal point for climate change issues in the Caribbean. It has also been recognised by the United Nations Institute for Training and Research as a Centre of Excellence.

3.1.1 Status of research

Status of research capacity for data collection

The research described above requires a significant amount of datasets of sufficient temporal length and from all territories across the Caribbean region. The task of collecting and managing this data is spread across a number of institutions both within and outside the Caribbean region. One of the largest regional institutions involved in coordinating this effort is the Caribbean Institute for Meteorology & Hydrology (CIMH).

CIMH maintains a climatology database that contains data recorded at stations maintained by National Meteorological Services that are members of the Caribbean Meteorological Organization. These countries include Anguilla, Antigua & Barbuda, Barbados, Belize, the British Virgin Islands, the Cayman Islands, Dominica, Grenada, Guyana, Jamaica, Montserrat, Saint Lucia, St Christopher (Kitts) & Nevis, St Vincent & the Grenadines, Trinidad & Tobago and the Turks and Caicos Islands. CIMH performs quality assurance checks on the data prior to making it available to the public and researches. The Institute was also designated as a Regional

Summary of current knowledge

Regional trends and scenarios can be predicted with a fairly high level of certainty for the 21st century for the following parameters:

- *temperature: (> 90% probability) that Caribbean temperatures will increase but the extent will depend on actual green house gas emissions. IPCC Fourth Assessment Report (AR4) report states a rise between 1.4o and 3.2 o C for the Caribbean by the end of the 21st century (IPCC 2007);*
- *precipitation: (> 66% probability) drying in the Greater Antilles in June, July and August;*
- *sea level rise: (>66% probability) is likely to continue to rise on average around the small islands of the Caribbean, close to the global mean of 0.18 to 0.59m up to 2090s;*
- *hurricanes: (>66% probability) global increase in hurricane intensity with larger peak wind speeds and heavier precipitation (IPCC 2007).*

Meteorological Training Centre by the World Meteorological Organisation in 1978 in recognition of the high standard of its training programmes. Students from all parts of the Caribbean and beyond are trained in such branches of meteorology as weather observing, forecasting, radar and satellite meteorology, instrument maintenance, agro-meteorology, and climatology, and in operational hydrology. CIMH maintains a staff complement of approximately 10 academic/research staff and 17 technical staff with expertise in weather forecasting, data mining, running and assessing climate models.

The Instituto de Meteorologia (INSMET) in Cuba also maintains a large database of climate data for 68 stations. These stations have in general at least 30 years of daily and tri-hourly data with some stations having time series that go back 100 years. Most stations have not been moved from their original location and those that were moved have had correction factors applied to the data to account for the relocation. All of the meteorological data for Cuba has been digitised and a quality control process implemented to minimise errors. In addition to the measurement of standard meteorological parameters, specialised meteorological stations exist that provide solar radiation, upper-air data, agro-meteorological and air quality and pollution. Other regional databases are held by the Caribbean Climate Interactive Database and the Universidad Nacional Autónoma de México.

Sources of climate data are also available from global organisations such as:

- The Climate Research Unit at the University of East Anglia, UK.
- Climate Prediction Center Global Climate Data and Maps, USA.
- International Research Institute for Climate and Society, USA.
- National Centers for Environmental Protection, USA.
- Global Climate Observation System, Switzerland.

Status of research capacity for climate change scenarios and models

As mentioned above, CCCCC is responsible for coordinating regional research on climate change and promoting international collaborations for specialised scenarios and modelling studies. It works in close partnership with several research groups in the Caribbean, including the Climate Studies Group Mona (CSGM) in the Physics Department of the University of the West Indies. CSGM was formed in 1994 with the following objectives:

- to investigate and understand the mechanisms responsible for a) the mean climate and b) extremes in climate in both Jamaica and the wider Caribbean;.
- to use this understanding to predict climate on a seasonal and annual basis; To promote awareness of global change and renewable energy resources; and
- to investigate and promote the advantageous uses of climate prediction in socio-economic sectors.

CSGM has three academic staff attached to the Physics Department and two technical staff. Part of its strength lies in its ability to attract postgraduate students at the M.Phil. and Ph.D. levels, and the fact that it has capability in global, regional and statistically downscaled modelling. Computer facilities are adequate for computational purposes but storage of model runs is still a problem.

The Joint Institute for Caribbean Climate Studies is a newly-created organization funded jointly by the University of Puerto Rico, and various local and federal government agencies. It is housed at the University of Puerto Rico, Mayaguez campus on the west coast of Puerto Rico. Its purpose is to provide an overarching infrastructure for researchers from university and federal agencies to work on problems concerning climate and environmental change in the Caribbean region.

INSMET has the demonstrated capacity for working on interdisciplinary and multinational projects, and can provide reliable information for the entire Caribbean in terms of regional weather forecasting and some detailed meso-scale information.

International collaboration on climate change has strengthened with CCCCC as the facilitator. Within the Caribbean region there is currently a core group of researchers and technical staff from the various organisations mentioned above, backed up by research students, capable of conducting climate change research.

3.1.2 Research gaps and capacity needs

Despite much progress in recent years, the resolution of regional climate models still does not allow reliable projections to be made at the national level. CCCCC is addressing this issue by increasing the number of models to which the region has access, drawing on the ensemble of 16 global models from the UK's Hadley Centre. However, in order to improve the accuracy of regional scenarios and facilitate the process of downscaling global

climate models to higher resolution regional models, the following needs and key data gaps were identified:

- increase the density of monitoring stations;
- capture daily station data of sufficient temporal length (30 years or more) for scenario generation via statistical means;
- capture secondary or derived information (e.g. from non-traditional archives such as records of sugar plantations, agricultural and hydrological bodies);
- data on wind, sea surface temperature, radiation, relative humidity and evapotranspiration; and
- information on the effects of El Niño Southern Oscillation, North Atlantic Oscillation and variability in tropical cyclones.

A priority issue is the need for improved management of climate data. This includes improved regional coordination in data collection and the need for data to meet the adopted global and regional standards. There is concern that considerable amounts of relevant data exist but are not in the digital format needed for modelling. There also needs to be a better mechanism for dissemination of climate data and records of metadata (who is holding what). In order to begin to address this issue the CCCCC received a grant from the Caribbean Development Bank in 2008 to establish an information clearing house.

> *"A priority issue is the need for improved management of climate data."*

One of the key capacity constraints that was identified is the small pool of professionals who can combine disciplines, such as meteorology and the biosciences. There is also a limited number of professionals with the skills to effectively assess and/or examine vulnerability or adaptation. This is hindering the development of biodiversity models at the regional and national levels, which are lagging behind. Available biodiversity models, such as UNEP's GLOBIO and the UN Food and Agriculture Organisation's IMPACT model for food and crops have spatial coverage at a grid scale that is too coarse for the small islands of the Caribbean region. It was suggested that collaborations should be developed between climate change and biodiversity modellers to soft-link and downscale these models.

There is also concern about the 'aging' cadre of professionals in the meteorological institutions of the region. These constraints often result in consultants from outside the region being hired, who leave their results but not their methodologies, so knowledge is not effectively transferred. The human capacity constraints are exacerbated by technical constraints such as the high cost of maintaining and calibrating meteorological instruments, which has resulted in a gradual deterioration of the meteorological network. There are also not enough high-performance computers and massive data storage systems to generate useful and high-quality information for forecasting purposes and for the research community.

3.2 Climate change impacts on coastal and marine biodiversity (WGII)

Coastal and marine biodiversity is critical to the region's socio-economic development. The livelihoods of most communities are interwoven, either directly or indirectly, with the many ecosystem products and services of the coastal and marine areas. Scientists have an important role to play in understanding how climate change will affect these ecosystems and in planning adaptation strategies. In the last three decades, the rapid pace of tourism development, urbanisation and population growth throughout the Caribbean, has presented huge challenges to policy-makers, planners and environmental managers. It is therefore important to consider the emerging threats from climate change within the overall context of existing environmental pressures that affect most Caribbean islands, such as habitat loss, deforestation, coastal erosion, pollution and over-fishing.

3.2.1 Status of research

In the past, taxonomists and natural scientists have been attracted to the richness of the Caribbean's coastal and marine biodiversity. More recently, interest in the sustainability of fisheries and the impact of widespread coastal development has directed much of the research towards examining anthropogenic impacts on individual species and ecosystems. Research on the effects of climate change on the region's biodiversity is still in its infancy but growing in urgency as the scale of the potential problems emerges. Much of the climate change research has focused on certain species, e.g. sea turtles, and particular ecosystems, e.g. coral reefs.

Emergent coastal wetlands

Emergent coastal wetlands, particularly mangrove forests, are an important resource in the insular Caribbean. Despite attempts to protect them through coastal management and planning programmes (e.g. Ramsar sites), there is still a net loss of wetlands across the region because of landfills, garbage dumping, vegetation clearing, reclamation, pollution and hydrological alterations. Overall global climate change is expected to exacerbate the loss and degradation of mangrove forests and their species. Mangroves are especially vulnerable to the impacts of sea level rise since they often have limited space to move landward due to seawalls and other types of coastal development.

Responses to climate change are likely to be highly variable and site specific. For example, if sedimentation rates keep pace with rising sea levels, mangrove forests could remain largely unaffected. In some instances, increased salinity may result in reduced seedling survival and growth rates and saline intrusion may result in the loss of freshwater wetlands. On the other hand, research indicates that higher atmospheric carbon dioxide levels, rising temperature and increased precipitation could increase mangrove productivity and expand the geographical range of some species.

Beaches

Globally it has been shown that 70% of the world's sandy beaches are eroding. This statistic also applies in the Caribbean, according to monitoring studies at 200 sites in nine eastern Caribbean territories. Tropical storms and hurricanes appear to be the dominant factor influencing erosion, with many beaches failing to return to their pre-hurricane levels. Beaches respond to sea level rise by retreating inland at approximately 100 times the rate of sea level rise. However, when constrained by sea defences, coastal infrastructure or changes in topography, beaches narrow and eventually disappear.

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Coastal forests, which used to be associated with Caribbean beaches, have been largely destroyed, or reduced to narrow strips of vegetation, as a result of clearing to make way for coastal development. They are likely to be further diminished due to stronger hurricanes and accelerated sea level rise.

Coral bleaching in Tobago. Source Buccoo Reef Trust

Seagrass beds

Seagrass beds are important nursery habitats and play a key role in the connectivity of coastal ecosystems. Seagrass beds have suffered because of increasing coastal development, dredging and ship traffic. Climate change impacts on seagrass beds have received little attention to date. Potential threats from climate change may come from rising sea level, changing tidal regime, localised decreases in salinity, damage from ultraviolet radiation, and unpredictable impacts from changes in the distribution and intensity of extreme events. Higher carbon dioxide concentrations may, however, increase productivity.

Coral reefs

Coral reefs form an important part of the economic foundation of the region. They support fisheries and function as natural breakwaters that protect shorelines. Reef products are used extensively for food, building materials, pharmaceuticals and the aquarium trade. In addition, reefs have become a major part of the tourism product for the region.

Since the 1970s, research on Caribbean coral reefs has clearly demonstrated their vulnerability to anthropogenic impacts, in particular coastal pollution, sedimentation and overfishing, all exacerbated by rapid coastal development. Consequently, coral reefs are considered to be in crisis, and this is well-documented in the literature. The causes of this crisis are not only the stress factors mentioned above, but a complex mixture of both human-imposed and climate-related stresses. They include factors such as outbreaks of disease, which have suspected, but unproven, connections to both human activities and climate factors.

> *"The most direct evidence of the impact of climate change on coral reefs comes in the form of coral bleaching, which can be triggered by a 1.0°C increase in temperature."*

More recent research on the effects of climate change is highlighting the new and heightened vulnerability of coral reefs. The most direct evidence of the impact of climate change on coral reefs comes in the form of coral bleaching, which can be triggered by a 1.0°C increase in temperature. Bleaching refers to the loss of a coral's zooxanthellae, which are symbiotic microalgae essential for reef building and growth. No incidents of mass coral bleaching were formally reported in the Caribbean before 1983. In 2005, Caribbean reefs experienced a major bleaching event, with massive declines of coral cover across the entire Caribbean Basin. Mass bleaching of corals in the past two decades has been linked to El Niño events, which have increased in frequency, duration and severity since the 1970s, though the exceptionally high sea water temperatures in 2005 have also been partly attributed to climate change (Donner, Knutson and Oppenheimer 2007).

Other aspects of climate change, such as an increase in the intensity of hurricanes and the frequency of intense rainfall events, will increase coral mortality on near shore reefs from sedimentation, lower salinity and physical damage. Healthy coral reefs are expected to keep pace with sea level rise, but the cumulative effects of the threats mentioned above are likely to weaken coral reefs and reduce their resilience. Projected increases in atmospheric carbon dioxide may drive a reduction in ocean pH, reducing calcification rates of calcium carbonate producers including corals. Perhaps the most profound and widespread changes in Caribbean coral reefs in the past 30 years have been attributed to disease, though the reasons for this sudden emergence and rapid spread are not well known. Warming can increase the virulence of pathogens and recent research suggests that the trend of increasing coral disease will continue and strengthen as global temperatures increase.

Coastal and pelagic fish species

Most of the fishery resources of the island shelves, such as reef and estuarine fish, lobster, shrimp, conch and others, as well as the deeper demersal resources (mainly snappers and groupers) are considered to have been overexploited since the 1980s. Many of these resources have been affected by coastal development, pollution and habitat loss. Large offshore pelagic fish stocks are generally considered to hold the greatest potential for development in the islands, though the status of the resource is highly variable depending on the species. The existing information about resource assessment and management of the main fisheries in the Caribbean islands is incomplete.

Studies have shown that climate change will decrease fish density and biomass on reefs because of a reduction in coral cover from bleaching and algal overgrowth. These studies suggested that fish biodiversity is also threatened wherever permanent reef degradation occurs. Climate change is also predicted to drive species ranges toward the more cold waters potentially resulting in widespread extinctions where dispersal capabilities are limited or suitable habitat is unavailable. It may strongly influence distribution and abundance through changes in growth, survival, reproduction, or responses to changes at other trophic levels. Projections are still poorly understood but could have profound effects for food security and coastal livelihoods in the Caribbean. The Caribbean coastal waters periodically experience extensive algal blooms that

> *"The Caribbean coastal waters periodically experience extensive algal blooms that affect living resources, local economies and public health."*

affect living resources, local economies and public health. Harmful algal blooms are usually associated with upwelling systems which could be affected by climate change and variation in wind regimes.

Sea birds

The Caribbean is known for its rich abundance of seabirds, both resident and migratory, and its unusual mix

of northern and southern species. These birds depend on the sea for food and the islands and cays for rookeries and nesting habitats. In general, research on the possible impact of climate change on seabirds and coastal waterfowl focuses on North America and Europe. Bird life cycles and behaviour are closely related to changing seasons, so it is expected that climate change will generally affect bird seasonal responses, egg laying dates, migratory timing and habitat loss.

Marine mammals

Six species of baleen whale, twenty-four species of toothed whale, one sirenian (the West Indian manatee), and a pinniped (the Caribbean monk seal, now considered extinct) have been recorded in the Caribbean. Of these, seven species are classified as endangered. Some species of cetacean may be resident in the Caribbean year-round, while others, such as the humpback whale, engage in long-distance migration. Research indicates that migratory marine mammal species are likely to be affected by climate change at some point of their life cycles, because they are subject to a wide range of environmental influences. While some species may increase in abundance or range, climate change will increase existing risk of extinction of some more vulnerable species. One of the greatest, climate change-related threats to marine mammals probably comes from changes in the distribution of food resources, such as fish and plankton, as a result of changing oceanographic conditions.

Sea turtles

Turtle populations have been declining over a number of years from loss of nesting beaches, pollution, over-fishing and diseases. Today the green, loggerhead and olive ridley turtles are considered to be "Endangered", while the hawksbill, leatherback and Kemp's ridley turtles are classified as "Critically Endangered". Climate change, and particularly sea level rise, is expected to add further pressure on turtles, mainly due to reduction in available nesting sites as a result of beach erosion. Rising temperatures are projected to affect sea turtle reproduction since sex is determined by temperature in the middle third of incubation. However, further research is needed on the effects of climate change on sea turtle reproduction.

3.2.2 Research gaps and capacity needs

As scientists start to appreciate the potential magnitude of the impacts of climate of change on coastal and marine biodiversity, the research gaps and capacity needs become more complex. The highly inter-connected nature of ecosystems means that the effects of climate change need to be understood at multiple scales, from the level of individual species to the level of the wider ecosystem, e.g. the Caribbean's large marine ecosystem. The following have been identified as priority research gaps:

- long term monitoring of changes in coastal and marine ecosystems;
- system connectivity;
- modelling of circulation changes in the Caribbean;
- sea level and sea surface data collection;
- vulnerability of key species to thermal stress and ocean acidification;
- vulnerability of key species to disease;
- assessment of threat from invasive species;
- algal blooms, plankton and ocean productivity;
- remediation techniques and ecosystem resilience; and
- effectiveness of specific conservation strategies, such as protected areas.

The final research need listed above was considered particularly important by participants at the September 2008 regional meeting, in view of the fact that research indicates only a small percentage of Caribbean marine protected areas (MPAs) are considered to be managed effectively. A multidisciplinary approach to research on MPAs, with strong collaboration between ecologists, social scientists and economists, is seen as essential to the establishment of regional networks of MPAs.

Englishman's Bay and Ridge Forest Reserve, Tobago.
Source Buccoo Reef Trust

3.3 Impacts of climate change on terrestrial biodiversity (WGIII)

As noted in Section 1, the Caribbean region has an unusually rich terrestrial biodiversity, such that

> *"...the Caribbean region has an unusually rich terrestrial biodiversity, such that Conservation International has identified the region as among the top eight "biodiversity hotspots" in the world."*

Conservation International has identified the region as among the top eight "biodiversity hotspots" in the world. As with coastal and marine biodiversity, terrestrial biodiversity is an intrinsic part of Caribbean life. It is essential for sustainable agriculture by ensuring the fertility of soils, natural pest control and the function of watersheds. With water and food shortages predicted to be major global issues in the coming century, preserving the productivity of soils and the healthy operation of water catchments is of fundamental importance to the well being of Caribbean people. The importance of forest cover in preventing flash floods, soil erosion and mudslides was recently demonstrated during the 2008 hurricane season by the stark contrast in the numbers of casualties in Haiti (high casualty numbers, very low forest cover), and Cuba and the Dominican Republic (low casualties, high forest cover). A more detailed analysis of these contrasting scenarios is required but there are clearly important policy lessons to be learned about the linkages between forest cover and human well-being. Similarly, in the devastating Asian Tsunami in 2003, the linkages between coastal biodiversity and human well-being were clearly demonstrated by the benefits provided by mangroves in protecting coastal communities from extreme waves.

Due to the very large amount of literature available on the region's terrestrial biodiversity, it was considered impractical to attempt a regional literature review of the impacts of climate change. Instead, the assessment of the research status and knowledge gaps on terrestrial biodiversity was based on literature reviews conducted primarily on seven Caribbean countries chosen as representative of the region. These were Cuba, the Dominican Republic, Haiti, Antigua and Barbuda, Bahamas, Dominica and Jamaica.

3.3.1 Status of research

For the seven countries that were assessed in this project there is baseline information available on their terrestrial biodiversity. This information, however, is not equally complete for all islands and did not facilitate the identification of knowledge gaps for some taxonomic groups. In all the islands assessed, vegetation zones and ecosystems have been identified and characterised, though very few regional distribution maps were found. Vegetation maps of the Caribbean islands, produced by The Nature Conservancy, are available at (http://web.archive.org/web/20070808024621/http://edcintl.cr.usgs.gov/tnc/products/atlas.html). These maps provide a potential source of spatial information on biodiversity distribution, although the suitability of using these maps for modelling is unclear. Regarding habitat fragmentation, only the Cuban national map of vegetation fragmentation has been found. Such maps are very useful for evaluating projected future impacts of climate change on biodiversity.

Conservation International has produced a comprehensive summary of the Caribbean islands as a biodiversity hotspot. A downloadable species database of vertebrate species occurring in Caribbean Islands is available on its website. The database lists 4077 species of the vertebrate classes Amphibia, Aves, Mammalia and Reptilia. For each species the Class, Order, Family, Scientific Name, Common Name and Threat category is included.

A Database of the Fungi of the Caribbean is also available as an annotated checklist with electronic distribution maps at (www.biodiversity.ac.psiweb.com/carimaps/index.htm). The database builds on almost 150,000 computerised database records, each representing an individual observation of a particular organism. Over half of the records refer to fungi. Each map shows the distribution of a single fungal taxonomic record from the insular Caribbean.

The web page of the Cuban Clearing Housing Mechanism has a compilation of Cuban information on biodiversity. The website (www.ecosis.cu/chm/chmcuba.htm) is based on the Network for Information on Biodiversity (in Spanish, RINBIO) of the National Centre for Biodiversity, which is located at the Institute of Ecology and Systematic in Havana. The information available on the webpage includes links to documents, collections, publications, researchers, institutions and databases (e.g. 75 databases on fauna, flora, fungi, endemism, and other topics related to biological diversity).

Status of research on climate change impacts

The literature review conducted on the seven Caribbean countries revealed that almost no research has focused on the effects of climate change on terrestrial biodiversity. A study from Cuba has reviewed climate change impacts, vulnerability and adaptation in relation to the island's biodiversity. This study incorporated the outputs of the General Circulation Models with the floristic composition of six phytogeographic districts in Cuba. Rainfall and the aridity index were found to have a negative correlation with plant composition, suggesting that the endemic plant species composition would change significantly with climate change.

On some islands, such as Dominica, the mountainous interior has a pronounced altitudinal zonation, which is likely to be affected by any changes in the climate. Assuming a cooling rate of 1oC per 150 metres of altitude, a projected increase of 1.7 o C (low IPCC scenario) would elevate vegetative zones by 260 metres. In the high IPCC scenario (3.5 o C), the elevation would be elevated by 530 metres. Under this high temperature scenario, elfin woodlands could completely disappear from Dominica, and some species unique to the Caribbean would likely be lost.

The projected increase in hurricane intensity is a major concern for Caribbean biodiversity. Natural disasters, per se, are not a threat to biodiversity as they are part of nature. However, the effects of natural disasters are magnified when they occur in ecosystems that are already vulnerable, due to human factors such as pollution, land clearing and over-harvesting. Forest biodiversity could be severely affected by the projected increase in extreme weather events, as adaptation responses on small islands are expected to be slow, and the impacts of storms may be cumulative. Storms result in habitat destruction by breaking branches, defoliation, debarking, loss of crowns and complete uprooting of trees. The resulting openings cause the forest to be less resistant to strong winds and therefore less resilient to natural disasters. In Puerto Rico, for instance, a study revealed that hurricane-induced mortality of trees after 21 months was 5.2%/yr, more than seven times higher than background mortality levels during the non-hurricane periods.

Strong winds can also have negative effects on wildlife when faced with the additional pressures of droughts, floods, or increased hurricane frequency. Many species may suffer from the loss of feeding grounds, nesting and roosting areas. Hurricane David, for example, caused the devastation of feeding and nesting sites of Dominica's two endemic parrots. The populations of these endangered parrots reached critical low levels (60 individuals of A. imperialis, and 200 of A. arausiaca).

Status of protected areas

Each of the countries for which reviews were conducted has a system of protected areas. However, information on the degree of biodiversity protection, or coverage of biodiversity by the established protected areas, is not always available. Also, current management plans of protected areas do not take climate change into account.

The Protocol Concerning Specially Protected Areas and Wildlife (SPAW) came into force in 2000 and was created at the initiative of the Caribbean countries to provide region-wide standards and mechanisms for harmonising conservation efforts across the region. Conservation International provides information on the SPAW Protocol and on a range of general regional issues such as the extent of the land area officially under conservation protection and the effectiveness of Caribbean protected areas on their website. There is international recognition of the need for much better management, monitoring, and enforcement of protected areas throughout the Caribbean, and the Caribbean islands are named as top priority for the expansion of the global protected areas network.

Status of research on agro-biodiversity

Agro-biodiversity is one of the main manifestations of the interaction between people and nature. The diversity of animals and plants used as food exists due to thousands of years of selection and care by rural people. The Convention for the Biological Diversity supports actions targeting the conservation and sustainable use of the biodiversity relevant to agriculture.

> *"There is the risk that these resources and traditional knowledge can be lost, and not only due to the projected impacts of climate change but also due to other socio-economic transformations."*

In all the countries that were assessed, the main plants and animals that have been or are subject to traditional use have been identified. This includes species that are relevant for food, medicine, and those that have been or are considered important genetic resources. In a limited number of countries the species used by people and the genetic resources are protected by law or are *in situ* collections. There is the risk that these resources and traditional knowledge can be lost, and not only due to the projected impacts of climate change but also due to other socio-economic transformations. As part of its National Biodiversity Strategy and Action Plan, Cuba has chosen to establish the National Network of Information on Agro-biodiversity and to link it to the Cuban Clearing Housing Mechanism.

All the countries covered in this study have put in place mechanisms for the *in situ* conservation of genetic resources. Some countries are more advanced and already have laboratories and ongoing national programmes, and have revised their national legislation for protecting such genetic resources. Other countries are at earlier stages. The conservation of genetic resources, and the creation of capacities for its management, conservation and study, represent the first steps for promoting the adaptation of agriculture and husbandry to the impacts of climate change

Caribbean countries like Antigua, Bahamas, Cuba, Dominican Republic, Haiti, Trinidad and Tobago and Jamaica are incorporated with the Inter-American Citrus Network located in Cuba. The research on citrus in the region includes research on phenology and the influence of climatic factors on the external morphological characteristics of early oranges. The research indicates that citrus crops are highly sensitive to changes in temperature and rain regimes and the projected climate change.

Root crops like cassava, potatoes and sweet potatoes play a significant role in the Caribbean diet. Several Caribbean islands have germoplasm collections for agricultural crops. The potential negative impacts on root crop production have been modelled using the climatic projection of the Hadley Centre Climate Change Model 2.

Rice is sown in at least four island states in the Caribbean: Cuba, Dominican Republic, Haiti and Trinidad & Tobago. Rice agro-ecosystems can be understood as seasonal and temporal wetlands, as they provide habitat to species communities typical to wetland areas. From a conservation point of view, water birds are the most visible users of rice fields (96 species in Cuba and 73 in Trinidad and Tobago). Rice fields, and their associated agricultural habitats, are used as foraging habitat by breeding, transient or wintering birds. But birds are not the only users; fishes, amphibians, reptiles and many invertebrates also use rice paddies. As climate change may reduce coastal wetlands, many species may become more dependent on rice farming, and future conservation and management measures should take this into account.

3.3.2 Research gaps and capacity needs

A review of the available literature revealed that information on the expected impacts of global climate change on terrestrial biodiversity in the Caribbean islands was very scarce. Only a few of the reviewed documents addresses the Caribbean islands from a regional perspective; more commonly they consider biodiversity-related issues at the scale of a country or at locations within a country.

There is a considerable body of knowledge and literature on Caribbean biodiversity, but very little of this information has been transferred to maps or geo-referenced databases. The need to address this is important for regional modelling and policy-making. A major research gap was also identified in the area of designing and developing models at the level of both species and ecosystems.

The frequency and extent of fires (e.g. forest fires) will be affected by changes in temperature and precipitation. The available information on fires for the region is limited and in many cases non-existent. This represents a substantial research gap, given the potential loss of habitat to fires and the consequent vulnerability to invasive species.

4. Research Agenda

The research agenda outlined in section 4.1 and 4.2 was developed at a Regional Meeting to review the CCBIC project findings, held in Port-of-Spain on September 24th and 25th 2008. The draft research agendas from the three working group reports were presented, discussed and prioritised, in order to reflect the collective views of regional experts on the research priorities for the next ten years.

It was decided that the research agenda should take into account existing obligations of Caribbean countries under the Convention on Biological Diversity (CBD), in particular the following priority actions:

- create viable networks of protected areas (PAs) that are resilient to climate change;
- identify species, e.g. coral, that are resilient to climate change in order to use those species for restoration projects; and
- implement adaptation and mitigation measures in land-use and coastal zone planning and strategies to strengthen local level resilience to climate change.

This overlap reinforces both the urgency and opportunity for Caribbean islands to meet their obligations under the CBD while simultaneously pursuing national climate change adaptation strategies.

4.1 Research agenda for climate change models and scenarios

To support the identified research priorities, the following enabling activities were proposed:

- ***Data rescue***

Data rescue would be coordinated by the Caribbean Institute of Meteorology and Hydrology in collaboration with CCCCC and CSGM, and INSMET.

- ***Coordination of monitoring and modelling***

CCCCC would take responsibility for coordinating the monitoring and modelling of sea surface temperatures, acidification and ocean circulation in the region. It was agreed that modelling storm surges should include different scenarios for beach protection, coastal ecosystem type and coastal infrastructure.

4.1.1 Monitoring biodiversity-related variables

- Creation of a regional network of climate data relevant to understanding biodiversity vulnerability to climate change.
- Consultation with biodiversity specialists about the type of data needed.

4.1.2 Analysis of model runs

- Data analysis of all PRECIS (Providing Regional Climates for Impact Studies) model runs.
- Massive data storage and support for graduate students.
- Explore possibility of establishing nodes for data storage in region through the clearinghouse at CCCCC.

4.1.3 Reducing uncertainties in statistical downscaling

- PhD research project to obtain averages of outputs from 21 IPCC global climate models in format suitable for statistical downscaling for any island in the Caribbean, focusing on rainfall, stream-flows and temperature initially.

4.1.4 Caribbean Climate Atlas

- Production of a Caribbean Climate Atlas by the Climate Studies Group Mona of all GIS-based data showing climatology, variability and scenarios.

4.1.5 Climate and biodiversity - correlation studies

- Impacts of climate variability and climate change on fisheries.
- Impact of climate variability and climate change on drought and forest fires.

4.1.6 Simulating reforestation of Haiti

- Multi-disciplinary project using regional climate models to simulate what would happen in terms of impacts on human well-being and climate if Haiti were reforested.

- Development of reforestation and land use plans that would generate carbon credits and improve human well-being provided that the underlying socio-economic issues are also simultaneously addressed.

4.1.7 Coupling climate and biodiversity models

- Soft linking of climate change and biodiversity models at regional level.

4.2 Research agenda for biodiversity

To enable the research priorities listed below, it was decided that long-term monitoring of changes in coastal and marine ecosystems should be strengthened through the use of existing regional nodes such as the Institute of Marine Affairs in Trinidad and Tobago.

The research agenda is divided into six thematic areas. Within these thematic areas priority will be given to research that is multi-disciplinary and that builds capacity of local actors and communities if involved. When possible, research should also include an assessment of the application of research findings and help develop good practices based on lessons learned.

- Linkages between ecosystem services, human well-being and climate change
- Resilience and restoration
- Agro-biodiversity
- Protected areas
- Vulnerability assessments
- Communication and outreach

4.2.1 Linkages between ecosystem services, human well-being and climate change

Multi-disciplinary studies that examine the linkages between climate change, human well-being and ecosystem services are identified as a priority thematic area of research. An understanding of these linkages is critical for the formulation of balanced and cost-effective adaptation strategies, and for a better appreciation of the often undervalued role of biodiversity conservation in maintaining the ecosystem services that are vital for human well-being (e.g. soil fertility, clean water supplies, micro-climate regulation, fisheries productivity, coastal protection). The topics listed below are considered particularly important.

- Innovative pilot projects on the economic valuation of environmental goods and services, which include the development of models that estimate the value of regulating and cultural services of biodiversity. Such models should include an analysis of the effects of climate change on these values.
- Analysis of case studies that demonstrate good practice in terms of the nexus between conservation and human well-being. The analysis should include how the projected impacts of climate change will affect socio-economic and environmental conditions, with recommendations for appropriate adaptation strategies.
- Analysis of the impacts of climate change on tourism, in particular tourism dependent on natural resources (e.g. reefs, beaches, turtles) and research tourism.
- Analysis of the impacts of climate change on the ecosystem services that support human settlement in the coastal zone. This could be, for instance, an analysis of the changes in the ability of coral reefs and/or mangroves to protect coastal areas, as well as a cost-benefit study of various adaptation strategies.

4.2.2 Resilience and restoration

This thematic area focuses on applied research targeted at selected sites, which may benefit from specific interventions that strengthen the resilience of the ecosystems and restore biodiversity. The research should build on existing case studies, and explore innovative approaches, in order to develop replicable solutions for the Caribbean region. The research topics listed below were identified as particularly important.

- Research aimed at increasing the resilience of beaches. Rising sea levels and intensifying storm events will increase beach erosion in many areas. One particular concern is the negative impact this will have on the availability of suitable nesting sites for marine turtles. Turtles are considered to be an important indicator species for climate change impacts and have a Caribbean-wide interest.
- Research aimed at increasing the resilience of coral reefs. Coral reefs are particularly important to the Caribbean region because of their high value to fisheries, tourism and coastal protection. They are also particularly vulnerable to the effects of climate change and therefore research is needed to determine the best

strategies for building their resilience and capacity for adaptation.

- Research aimed at increasing the resilience of mangroves and other coastal ecosystems. Mangroves are essential nursery habitats for many species and play a critical role in coastal protection during storm events. As with beaches, they are threatened by increasing development on the landward side and rising-sea levels on the seaward side. To address this phenomenon, known as "coastal squeeze", targeted research linked to land-use planning and policy will be required.
- Research aimed at increasing the resilience of forests. Projected changes in the temperature and rainfall in the Caribbean will have profound effects on soil moisture and the incidence of forest fires, disease, and invasive pests. In order to strengthen the resilience of Caribbean forests and their associated biodiversity, research is required that demonstrates the benefits of reforestation, watershed management and appropriate land-use planning.

4.2.3 Agro-biodiversity

Agricultural biodiversity is a subset of biodiversity and underpins the development of all food production. Agro-biodiversity includes domesticated crops and animals as well as their wild relatives. It also includes non-harvested species that support agriculture, such as pollinators and soil bacteria. Research priorities for the conservation of agro-biodiversity include:

- capturing traditional knowledge relevant to agro-biodiversity;
- developing in- and ex-situ conservation activities and systems of access that produce economic and livelihood benefits for the local community; and
- developing national protocols for protecting the intellectual property associated with traditional knowledge and practices in agro-biodiversity.

4.2.4 Protected areas

The creation of protected areas (PAs) is potentially one of the most effective approaches for the conservation of biodiversity and is generally included as an important component of national environmental management plans. Climate change has strengthened the arguments for PAs, on the basis that ecosystems inside PAs are likely to be more resilient than unprotected ones, and therefore better able to adapt to a changing environment. Climate change also strengthens the need for networks of PAs that take into account the ecological connectivity that exists across geographic regions as well as the potential migrations of species and ecosystems in the future.

Research in this thematic area should use a multidisciplinary approach to examine the social, economic, political and ecological factors that contribute to the effectiveness of PAs in meeting their objectives. Research should also try to integrate with existing regional projects (e,g. the Integrating Watershed and Coastal Area Management and Caribbean Large Marine Ecosystem projects) and with commitments under international agreements (e.g. CBD, Ramsar). The research priorities that have been identified are:

- identification of ecosystems that have high natural resilience;
- assessment of existing protected areas to see to what extent they are vulnerable to climate change;
- assessment of existing protected areas to see to what extent they are addressing climate change issues;
- assessment of effectiveness of current protected areas, and analysis of the factors that make some more successful than others in achieving their objectives, using a multi-disciplinary approach; and
- application of the findings to improving the management of selected terrestrial and marine protected areas.

4.2.5 Vulnerability assessments of selected species and ecosystems to climate change

The vulnerability of many species and ecosystems to climate change is unknown, and therefore a key area of concern for both the conservation of biodiversity and the security of livelihoods, human health and food production in the Caribbean. Research targeted at assessing the vulnerability of selected species is therefore a priority thematic area, with the topics listed below being of particular concern.

- Vulnerability assessments of keystone species critical to the provision of ecosystem services (e.g. pollinators, corals).
- Vulnerability assessments of indicator species of climate change such as turtles, amphibians and mosquitoes.

- Vulnerability assessments of commercially important species in agriculture and fisheries.

4.2.6 Communication and outreach research

Effective communication is a prerequisite for effective climate change adaptation, and strategies are needed both for the "adaptation community" and the wider public. It has been identified as a key thematic area in this research agenda because little is currently known about what types of communication are most effective in bringing about the desired changes of opinion and behaviour in the key target audiences. Effective outreach will necessitate increased dialogue between scientists and communication specialists who have the ability to "translate" what is often technical and complex information to target audiences who may currently be misinformed, sceptical or disinterested. Regional communication strategies face the additional challenge of linguistic and cultural diversity. The following research activities are therefore considered a high priority:

- to test and evaluate a range of communication approaches in terms of their effectiveness in modifying behaviour and attitudes.
- to analyse how to increase the Caribbean's voice, and influence the adaptation and mitigation discourse at the international level.

The steps involved in defining the communications research agenda and research projects would be to:

i. identify what communication research data exists in the region and where;
ii. analyse behaviours and attitudes and develop a baseline for future comparison;
iii. develop and test a range of communication and advocacy tools;
iv. evaluate what has worked and why; and
v. disseminate information about what worked.

The research questions listed below were specifically suggested.

- How can Caribbean countries collaborate and effectively apply pressure to first world countries to cut back on emissions and commit to greater mitigation efforts?
- How can tourists be sensitised so that they become advocates for changes in their countries?
- How can communication efforts stimulate collaboration between different organisations and sectors in implementing mitigation and adaptation strategies?

5. Capacity Building Agenda

The need for increased capacity for research on the impacts of climate change was recognised by all three working groups as a regional concern. Capacity needs fell into two main categories - human capacity and technical capacity.

5.1 Human capacity

5.1.1 Data collection

It was noted that because of the relatively small populations of Caribbean SIDS, it is unrealistic to expect each country to develop expertise in the each of the disciplines relevant to research on climate change. There is therefore a need for greater regional collaboration and for the development of regional centres of excellence where resources could be pooled and shared. This would require a fundamental shift in mindset in terms of data sharing between institutions. A regional directive on data sharing and the creation of data sharing mechanisms would facilitate this process.

Greater capacity for data collection and monitoring is required throughout the region. This could be met in part by training practitioners such as environmental managers and their staff, community stakeholders and volunteers (both local and tourism volunteers). Successful examples of community and volunteer involvement in data collection exist in many countries, such as in Costa Rica (Instituto Nacional de Biodiversidad arrangement), Tobago (Coral Cay Conservation), Trinidad (Earthwatch) and Cuba (Volunteer network).

Rapid assessment of biodiversity hotspots using standard methodologies could also be facilitated by regional teams (e.g. roving data collection teams) that could work in partnership with local stakeholders.

Data collection using remote-sensing technologies could dramatically reduce – though not eliminate - the need for data collection in the field. The Surveying and Land Information Department at the University of the West Indies, St Augustine, Trinidad provides training in remote sensing techniques.

Agreements with international agencies involved in providing satellite imagery and data also need to be developed further to facilitate access to spatial information

> *"Greater capacity for data collection and monitoring is required throughout the region.... Data collection using remote-sensing technologies could dramatically reduce - though not eliminate - the need for data collection in the field."*

by universities and civil society organisations. CCCCC has a Memorandum of Understanding with the National Oceanographic and Atmospheric Administration and the Centro del Agua del Trópico Húmedo para América Latina y El Caribe and is currently exploring mechanisms for the region to get access to finer resolution data (e.g. vegetation, radiation, altimetry).

Cuba in particular has some difficulties accessing satellite information because of the price of fine resolution data. Certain agencies such as the Japan Aerospace Exploration Agency and Planet Action make satellite data available at either low or no cost. They are looking for collaborators to develop uses of new sensors.

5.1.2 Multidisciplinary expertise and process facilitation

There is a specific need for more graduate student research and cross-disciplinary training in climate change. This is to address a regional shortage of professionals with interdisciplinary expertise in meteorology/biosciences and vulnerability/ adaptation. This could be done by funding or facilitating interdisciplinary research/dialogues between climate researchers and scientists of other sectors such as biodiversity. There is also a lack of expertise in modelling, in particular biodiversity-modelling skills.

Other areas where training and the development of skills are needed are in environmental economics (accounting and valuation of ecosystem goods and services), conservation planning, and protected area planning and management.

There is also a need to build human and institutional capacity for facilitating participatory processes. This would include strengthening skills in stakeholder mobilisation and identification, participatory planning and management, conflict management, developing co-management arrangements. Key resource persons and institutes, such as CANARI, could be identified to provide such training.

5.2 Technical Capacity

The region's ability to develop better predictive models of the effects of climate change is limited because of a shortage of powerful computers and large data storage facilities. Also, while there is considerable technical capacity in many institutions for meteorological instrumentation, the acquisition of new instruments and technologies would greatly improve the efficiency of data collection.

The region needs better data-sharing mechanisms and information networks to facilitate collaboration and coordination. A number of regional initiatives are currently underway that offer research, capacity building or communication opportunities. These opportunities are frequently not taken up because of failures in communication networks.

There is also a need for better regional coordination on issues relevant to climate change at the political and negotiation level. CCCCC is a regional node with a sub-regional mandate for coordinating research on climate change, but has limited capacity for expanding this coordination to the policy and negotiation level.

6. Communication

Discussing vulnerability to climate change, Laborie, St. Lucia.
Courtesy Annalise Bayney

The project also highlighted the lack of effective communication between the scientific community and other stakeholders. Important partners such as teachers, policy-makers, politicians and the private sector need to be targeted by carefully focused, national and regional communication campaigns on climate change. Although CCCCC developed a Public Education and Outreach Strategy in 2004, it has not yet been implemented and there is currently no organisation taking the lead in coordinating and implementing a communication programme at the regional level.

In addition to the communications research agenda outlined above (see section 4.2.6), the regional meeting also discussed what should be the key objectives, messages and target audiences for a regional communication strategy (many of which are in line with those proposed in the CCCCC strategy).

6.1 Objectives

The following are considered the priority objectives of communications about climate change designed to effect behaviour and attitudinal change:

- to inform and build awareness of all Caribbean people;
- to 'democratise' science by 'translating' scientific knowledge into a form that is accessible to non-technical audiences;
- to empower people to become campaigners and advocates; and
- to increase the capacity of key climate change interlocutors to deliver messages effectively to their target audiences.

6.2 Target audiences

- Policy makers (technocrats and the political directorate)
- Individuals, with a particular focus on young people, whose future is most at stake
- Communities, with a particular focus on those in vulnerable areas
- Researchers
- CCCCC focal points
- Private sector
- Regional and international agencies
- Tourists
- Schools
- Media/journalists

6.3 Key messages

The core messages to be communicated about climate change are:

- ***Awareness Is Empowerment***

Getting the facts about climate change empowers you to act - adapt and mitigate. Find out where you can get information and what you can do to make you, your family and your community less vulnerable to climate change.

- ***A United Voice is a Stronger Voice***

As a region, there is need for a stronger unified voice advocating for increased mitigation efforts.

Examples of appropriate messages for specific audiences were developed and are cited in the workshop report (CANARI 2008).

6.4 Channels of communication

It was agreed that to be effective, communications about climate change must stay on the cutting edge of technology and that marketing/advertising agencies could be approached to develop campaigns. Other suggestions included:

- the identification of champions, particularly those who would appeal to young people (e.g. sportspersons);
- use of participatory video;
- use of theatre-in-education;
- use of popular 'conscious' performance artists; and
- use of blogs, YouTube and website portals (e.g. Climate Ark).

7. Conclusions

The need for multidisciplinary research and communication

Climate change is already affecting the region's biodiversity in many and profound ways, and this in turn is causing wide-ranging impacts on many sectors of human society. These impacts are projected to increase as climate change accelerates, presenting substantial threats to the region's sustainability and to the well-being of its citizens. Adaptation planning for climate change is a critical development priority for the region.

Perhaps more than any other area of research, there is a need to invest in climate change research. The proposed research agendas will require a multi-disciplinary approach, where climate scientists, ecologists, social scientists and economists combine their respective expertise for the development of effective adaptation policies. This holistic methodology will become an essential prerequisite for effective policy- and decision-making.

Improving existing measures for protecting biodiversity is a critical aspect of adaptation and the region needs to re-examine its conservation strategies and adopt a more pragmatic approach. This includes a greater focus on developing policies and laws that can be effectively implemented and that will produce tangible benefits to the resilience of ecosystems. The planning and effective management of protected areas is an example where improvements are needed. The project findings strongly support the need for investment in multidisciplinary protected area research in order to develop more realistic objectives and obtain greater benefits for both communities and ecosystems.

More emphasis needs to be placed on funding applied research. Adaptation is not only cheaper than remediation but many of the solutions would benefit the region with or without climate change. In most cases, addressing the region's existing environmental problems through active management will not only improve the resilience of the ecosystems and well-being of communities today, but will also place them in a better position to adapt toc limate change. Adaptation to climate change can be viewed as a 'no regrets' strategy for sustainable development.

Improved communication between policy-makers and scientists will also be essential for effective decision-making. In fact, better communication will be of mutual benefit to both policy-makers and scientists, as policy needs to play a greater role in driving research agendas. The need for more effective communication also exists between scientists, policy-makers and communities. Greater public awareness and understanding about adaptation policies are required to effect the necessary behavioural and attitudinal changes. Access to the relevant information will be essential in this process.

Mainstreaming climate change adaptation in national and regional policy

There is a strong case for the Caribbean to bring adaptation into the mainstream of national and regional policymaking, planning and development. Adaptation is the only way to deal with the inescapable impacts of climate change. Development cannot be sustainable unless it factors in climate impacts and natural hazards, and finds ways of reducing risk and minimising vulnerability.

Mainstreaming climate change issues into the national and regional policy and planning process does not require a dramatic departure from all that has gone before. It can be done in incremental ways by building onto existing policies and programmes. What is required is a commitment to deal efficiently with current climate, environmental, social and economic needs and vulnerabilities in an integrated and holistic manner.

By addressing the development challenges that have led to the accumulation of hazard and human vulnerability throughout the region, decision makers and planners will reduce the negative effects of climate change while bringing immediate benefits to communities and the environment. Adopting a regional approach will also maximise the use of the existing limited resources while fostering greater collaboration in other areas of development and research. Mainstreaming adaptation to climate change, at both the regional and national levels, is therefore a win-win proposition.

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Caribbean Natural Resources Institute

The Caribbean Natural Resources Institute (CANARI) is a regional technical non-profit organisation which has been working in the islands of the Caribbean for over 20 years.
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Our programmes focus on research, sharing and dissemination of lessons learned, capacity building and fostering regional partnerships.

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