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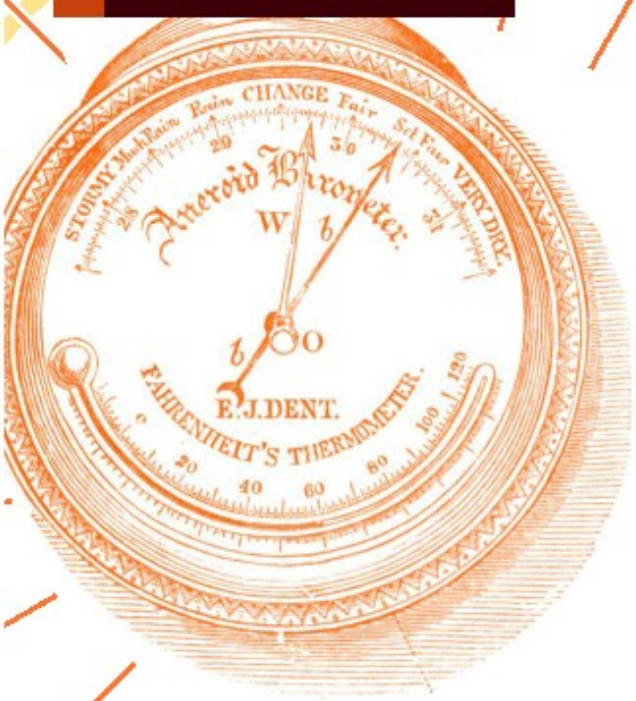

CLIMATE CHANGE IMPACTS ON TERRESTRIAL BIODIVERISTY IN THE INSULAR CARIBBEAN

Report of Working Group III, Climate Change and Biodiversity in the Insular Caribbean

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EXECUTIVE SUMMARY

This report, prepared by a group of Caribbean experts, focused on the insular Caribbean terrestrial biodiversity. The report has been produced in the framework of the project Climate Change and Biodiversity in the Insular Caribbean (CCBIC), which has been implemented by the Caribbean Natural Resources Institute, and supported by the John D and Catherine T MacArthur Foundation.

The goal of the Climate Change and Biodiversity in the Caribbean project is to develop a regional research agenda that will address gaps in our knowledge on the impacts of global climate change on Caribbean biodiversity, and identify the capacities that need to be developed for implementing a regional research agenda. The research agenda is intended to inform biodiversity management in the insular Caribbean for climate change adaptation in conservation that will support sustainable livelihoods, resilience building and vulnerability reduction in light of climate change impacts.

This report is based on a desk review of published and unpublished literature related to climate change and its impacts, vulnerabilities and adaptation as they relate to terrestrial biodiversity in the insular Caribbean.

The economy of Caribbean islands is based on natural resources. The livelihoods of the Caribbean people are based on the services that are provided by biodiversity and ecosystems. Currently, many of these goods and services are under severe stress by human activities. Climate change will add additional stress.

Information on expected impacts of Climate Change on the terrestrial biodiversity of Caribbean islands is rather scarce. Increase in average temperature, changes in precipitations patterns, and natural disasters related to climate change (drought, hurricanes, flooding) will have a negative impact on terrestrial biodiversity. This desk-top review and assessment involved the compilation and in-depth assessment of biological information relevant to future projects dealing with the evaluation of the impacts, vulnerabilities, and adaptation of terrestrial biodiversity to climate change was conducted. It covered seven Caribbean countries (Antigua and Barbuda, The Bahamas, Dominica, Jamaica, Haiti, Dominican Republic and Haiti).

The compilation of the available information on agrobiodiversity, and traditional knowledge on biodiversity, is highly recommended. The management of impacts of climate change on biodiversity should be based on the Convention for Biological Biodiversity´s ecosystem *approach*. The creation of a Caribbean information network to collect relevant information on climate change and biodiversity for the region is recommended. The projects and management of climate change impacts on biodiversity should be on a regional basis.

Science can help to ensure that decisions are made with the best available information, but ultimately the future of biodiversity will be determined by society (MEA, 2005)

1. Introduction

1.1 Background and concepts

The United Nations Convention on Biological Diversity (CBD) defines biodiversity as "the variability among living organisms from all sources including inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part This includes diversity within species, between species, and of ecosystems." The IPCC (2002) also emphasises these three levels of biological diversity; that is, genetic, species, and ecosystem. IPCC also considers biodiversity that occurs in both intensively (agriculture, plantation forestry) and non intensively (e.g., pastoral lands, native forests, freshwater ecosystems, and oceans) managed ecosystems. It also recognises the intrinsic value of biodiversity, irrespective of human needs and interests.

The CBD, the IPCC and our WG III report, recognises wildlife as a component of biodiversity. Based on a decision of the Conference of the Parties to the CBD, we considered the agricultural biodiversity as a broad concept that includes all components of the biological diversity that constitute the agro-ecosystems or that are relevant to food and agriculture (i.e., the variety and variability of animals, plants and micro-organisms at the genetic, species and ecosystem levels).

Ecosystems provide many services that are crucial to human well being. The ecosystem services are the benefits that people obtain from ecosystems. These include provisioning services such as food, water, medicines, timber and fibber; regulating services that affect climate, floods, pollination, seed dispersal, pest and disease control, wastes and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis and nutrient cycling. Ecosystems also play a critical role in biogeochemical processes that underlie the functioning of the Earth's systems. The human species, while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of ecosystem services. The changing human conditions (including climate change) drive, both directly and indirectly, changes in biodiversity and ultimately changes in the services provided by ecosystems (MEA, 2005). Some indigenous and

rural communities are particularly dependent on many of these goods and services for their livelihoods. In the Caribbean islands, the preservation of the traditional knowledge of biodiversity is crucial to the sustainable use of ecosystem services. The loss of such traditional knowledge, for example that related to medicine plants and agriculture, has had a direct negative effect on biodiversity and on the degradation of ecosystems, for instance by exceeding traditionally established norms for resource use.

The ecosystem approach is the key strategy for implementing the objectives of the CBD. This Convention constitutes the first binding document of international law dealing with the protection of biodiversity in a global and comprehensive way. Its purpose is to protect the diversity of genes, species, populations and ecosystems. The three main objectives of the Convention are: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources.

The ecosystem approach was developed as the primary framework for action to reach the CBD objectives. As such, its twelve principles describe essential cornerstones of a comprehensive strategy for the integrated management of natural resources aiming at striking a balance between conservation and sustainable use in an equitable way. The term “integrated management” is used to refer to the management of land, water and living resources across all land-use sectors and policy areas. The ecosystem approach requires the full participation of stakeholders in the decision-making processes of ecosystem management. The linking of ecological, economic and social aspects of biological diversity opens up a novel perspective that, in many respects, results in a paradigm shift in environmental and resource use policy. The ecosystem approach is a comprehensive concept promoting consensus and stakeholder support, the guidance and stimulus necessary for effective ecosystem management. The ecosystem approach does not preclude other management and conservation approaches. Its implementation is to be seen as an open process allowing for discretion in interpretation and actions.

We made an assessment of the available information on climate change impacts on the terrestrial diversity of plants, animals, ecosystems and fungi in the Caribbean islands, but some thematic areas like freshwater biodiversity (both surface and subterranean), soil biodiversity and bacterial diversity were not dealt with in this study due to constraints in time and availability of experts to carry out these particular assessments. It is well known that climate plays a key role in

the physiology and ecology of species. Factors such as the temperature and the availability of moisture (in terrestrial ecosystems) are among those that determine the niches for all species on earth (Biringer et al, 2005). The Caribbean terrestrial biodiversity will experience some of the most significant impacts from changes in water regimes induced by climate change. The projected increase in average air temperature may be important enough to cause changes in the microclimate of the high-elevation forest ecosystems of the region.

1.2 Methodology

The Group III on Terrestrial Biodiversity had the first expert group meeting in December 2007 (see Annex 1 for information on the experts). The meeting was planned for analysing the first literature review for the Caribbean islands. The review addressed climate change and terrestrial biodiversity for the Caribbean Islands, and includes numerous references. It addressed literature written mainly in English and Spanish. Annex 1 includes references with detailed summaries. The review was based on two literature surveys prepared by two postgraduate students during November and December 2007.

A meeting of the members of the Working Group was convened to conduct a preliminary assessment of the information available in the literature on the impacts of climate change on terrestrial biodiversity in the Caribbean and to confirm the format and content of the report to be prepared. The initial review of the literature revealed a scarcity of information on the inter-relationships between climate change and biodiversity in the region (see section 2.1).Besides the identification of knowledge gaps, and taking into account the scarcity of this type of information, the working group decided to include in the report an assessment and summary of biological information the relevant to the assessment of the impacts, vulnerabilities, and adaptation of terrestrial biodiversity to climate change (see section 2.2).

Due to the limited time available for preparing the report, the decision was taken to focus the assessment on seven Caribbean countries. The seven countries comprised:

- Spanish and French speaking islands:
    - Cuba – archipelago state with the largest island of the Antilles
    - Dominican Republic, and Haiti, the two countries that occupy the island of the Hispaniola.
- English-speaking islands:

- Antigua and Barbuda –small, low-lying, dry, Organisation of Eastern Caribbean States (OECS) country.
- The Bahamas – low-lying, dry, archipelagic country.
- Dominica – small, mountainous, water-rich OECS country.
- Jamaica – large, mountainous, country.

1.3 General information on the Caribbean biodiversity

The Caribbean region has been identified as a biodiversity "hottest hotspot" on the basis of its contribution to the world biodiversity (Myers et al 2000). The Caribbean region stretches over only 0.15% of the Earth's surface, while hosts 2.3% of the global original primary vegetation and 2.9% of the world's vertebrates (Myers et al 2000). It has been estimated that the rich flora of the Caribbean region comprises 7000 endemic species, although only 11.3% of the Caribbean primary vegetation remains.

These findings have prompted Conservation International to designate the Caribbean among the top 8 of the World's 25 "Hotspots", i.e., relatively small regions containing high percentages of endemic species. A comprehensive summary addressing the Caribbean Islands as Biodiversity Hotspot can be found on the website of Conservation International (www.biodiversityhotspots.org, Conservation International, 2007a). That summary, with 20 bibliographic references, structures the information in: Overview, Unique Biodiversity, Human Impacts and Conservation Actions. A downloadable list (Species Database) of Vertebrate Species occurring in Caribbean Islands is included, too. That 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. Most of the text information provided by the website of Conservation International can also be found in the website of the Encyclopaedia of Earth (www.eoearth.org, Conservation International, 2007b.)

The information provided by Conservation International on the Caribbean islands starts with a summary table that include the following data: Hotspot Original Extent (229,549 km^2); Hotspot Vegetation Remaining (22,955 km^2); number of Endemic Plant Species 6,550, Endemic Threatened Birds (48), Endemic Threatened Mammals (18), Endemic Threatened Amphibians (143) and Extinct Species (38); Human Population Density (155 people/km^2); and extension of Area Protected (29,605 km^2) and Area Protected in IUCN Categories I-IV (16,306 km^2) (Conservation International, 2007a.)

The section Overview addresses generalities (e.g., the countries) of the three large groups of islands that form the Caribbean Islands (i.e., the Bahamas, the Lesser Antilles, and the Greater Antilles). In addition, it gives an overview of the Caribbean topography, climate and vegetation (Conservation International, 2007a.)

The section on Unique Biodiversity provides a table of the total number of species and the number of endemic species of plants (13 000 and 6 550, respectively), mammals (89 and 41), birds (604 and 163), reptiles (502 and 469), amphibians (170 and 170) and freshwater fishes (161 and 65). The text includes comments on the distribution patterns of taxa, particularly on endemism, and on extinction (Conservation International, 2007a.)

The section on Human Impacts reviews major environmental degradation issues and human actions, such as: The introduction of alien species (the biggest threat to biodiversity in the hotspot), the arrival of the Europeans on the Hispaniola island in 1492, the influence on deforestation from historical major crops like sugar cane, and challenges coming from important current socioeconomic activities such as tourism and agriculture (Conservation International, 2007a).

2. Impacts of Climate Change on Terrestrial Biodiversity

2.1 Current knowledge of future projected impacts of climate change on the Caribbean terrestrial biodiversity.

For the Caribbean region, seven models project increased surface air temperature. Regarding precipitation, the range of projections is still large, and even the direction of change is not clear (Ruosteenoja et al. 2003, quoted by Nimura et al 2007).
Regarding Cuba, Suárez et al. (1999) and Ferrás et al. (1999) were among the first papers to review climate change impacts, vulnerability and adaptation in relation to Cuban biodiversity. The papers incorporate the outputs of General Circulation Models (GCM). Ferrás et al. (1999) studied the relationship between climatic variables and the floristic composition of the phytogeographic districts in Cuba with the aid of Geographic Information Systems (GIS) and multivariate analysis. Rainfall and the aridity index were found to have a negative correlation with plant composition. Suárez et al. (1999), based on the works by Ferrás et al. (1999), and the aridity index developed by López (1998), concluded that the endemic plant species composition of six phytogeographic

districts of eastern Cuba would change with the temperature changes projected in three General Circulation Models (GCM) for year 2100.

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. The IPCC Fourth Assessment Report anticipates an increase in the severity of extreme hydro-meteorological events such as cyclones (hurricanes), and specifically projects an increase in hurricane intensity (IPCC (IPCC WG II SPM 2007)). Forest biodiversity could be severely affected by these changes, as adaptation responses on small islands are expected to be slow, and the impacts of storms may be cumulative. For example, Ostertag et al. (2005) examined long-term tropical moist forests in Puerto Rico. Hurricane-induced mortality of trees after 21 months was 5.2%/yr, i.e., more than seven times higher than background mortality levels during the non-hurricane periods. These authors show that the resistance of trees to hurricane damage is not only correlated with individual and species characteristics but also with past disturbance history. Thus, individual storms cannot be treated as discrete independent events when interpreting the effects of hurricanes on forest structure. Lugo (2000) analysed the effects and outcomes on vegetation and forest if the Caribbean hurricanes increase in frequency and intensity.

Windstorms result in habitat destruction by breaking branches, defoliation, debarking and complete uprooting of trees. After Hurricane David (1979), at least 50% of all dominant tree species had broken branches and many had lost large portions of their crowns. The resulting openings in the landscape caused the forest to be less resistant to strong winds and therefore less resilient to natural disasters. The winds can also have negative effects on wildlife re faced with the additional pressures of droughts, floods, or increased hurricane strikes. In addition, they may suffer the loss of feeding grounds, nesting and roosting areas. Hurricane David, for example, caused the devastation of feeding and nesting sites of the two Dominica's endemic parrots. The populations of these endangered parrots reached critical low levels, i.e., 60 individuals of *A. imperialis*, and 200 of *A. arausiaca* (Commonwealth of Dominica, 2001, UNFCCC Initial National Communication).

Dominica's vegetation type, especially in its mountainous interior, has a pronounced altitudinal zonation due to climate. Such zonation is likely to be affected by any change in climate. For example, assuming a lapse rate of 1^{o}C per 500 ft, the low scenario of 1.7 ^{o} C would

elevate vegetative zones by 850 ft. In the high scenario (3.5 ^{o}C), the elevation would be of 1750 ft. Under this high temperature scenario, elfin woodlands could completely disappear, and some species unique to Dominica could be lost (Parry, 2001 personal communication, quoted by Dominica UNFCCC First National Communication, 2001.)

2.2 State of knowledge of biological information in selected Caribbean islands.

Based on the information mined for the islands Antigua, Bahamas, Cuba, Haiti, Dominican Republic, Dominica and Jamaica, a synthesis of the state of knowledge of biologic related information relevant to evaluating the impacts of climate change on biodiversity was prepared.

2.2.1 Island-based information

In order to complete the information relevant to the state of knowledge of the impacts of climate change on terrestrial biodiversity on the Caribbean islands, a data-mining approach has been used in each country subjected to an in-depth assessment.

- Information on the impacts of climate change on terrestrial biodiversity for **Antigua** was not found**.** Information is available on flora and fauna species, forest ecosystems, and soils including soil maps. There is very little data on invertebrates. In situ conservation of some plant resources is done. A list of plants traditionally used (e.g., for medicine) was done.
- Literature on the impacts of climate change on terrestrial biodiversity for **Bahamas** was not found**.** There is information available on the flora and fauna of the country. There are some conservation activities, and protected areas. Many genetic resources are identified.
- There is a reference of projected climate change impacts on biodiversity for **Dominica** (previously quoted, *Parry, 2001 personal communication)*. The country has documentation of the flora, fauna and natural vegetation. 20 % of forested land is under some protection. Experience on plant micro-propagation and a yam in situ bank exist. Wild plants used for food, medicine and industrial purposes have been listed.
- References on climate change impacts on **Jamaican** biodiversity were not found. Good knowledge of the island flora, fauna and vegetation exists. There are collections of native plants and crops plants. Good experience in tissue culture (University of the West Indies, Mona) and in vitro collections is available. There is a national park system, and protected areas.

- Suárez et al. (1999) obtained projected changes endemic plant species composition of six phytogeographic districts of eastern **Cuba** for 2100 (previously quoted). The authors considered the development of the protected areas system as the most important adaptation action to preserve the Cuban biodiversity. Flora, fauna and vegetation information is available on databases and maps. Information on traditional use of flora and fauna species is available. There is good experience on tissue culture and in vitro collection. Collections for agro biodiversity purposes exist. A national system of protected area is established. Information on Cuban biodiversity including databases, maps and links to institutions, researchers, publications (published papers) are available through the Cuban CHM-webpage.
- No literature on climate change impacts for **Dominican Republic** biodiversity was found. There is information available on the flora and fauna species, ecosystems, soil resources (soil maps included). Some groups like insects, algae, fungi, lichens and mosses have been poorly studied. The protected area system covers 20% of the country.
- The literature review did not find any reference on climate change impacts on **Haiti's** biodiversity. Haiti and Dominican Republic share the island La Hispaniola. Both countries have many common species and ecosystems. Haiti's known biodiversity is highly diverse and rich on endemic species. Haitian Government has officially identified a total of 35 protected areas, which cover about 6% of the national territory. However, the percentage of effective protected areas is evaluated at no more than 0.3% of the overall surface of the country. The country environment is highly degraded.

2.2.2 Biodiversity: species lists, ecology.

- For the islands that were assessed, there is baseline knowledge on their terrestrial biodiversity. However, the available knowledge is not equally complete for all islands. Species lists are available for all islands, although the compiled information has not facilitated the identification of knowledge gaps for some taxonomic groups.
- In all the islands the vegetation zones and/or ecosystems have been identified and characterised. The available information that was reviewed did not permit the assessment of the level of national and regional knowledge of the ecology of species and species and habitat zonation.
- In all of 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.

2.2.3 Assessment of information availability relevant to an assessment of climate change impacts on biodiversity.

- 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 scarce. This situation was true for the literature reviewed for the Spanish, English and French islands.
- Regarding the geographical scope of the references, only a few of the documents reviewed address the Caribbean islands from a regional perspective. In the most common situation a document would review biodiversity related issues at scale of a country or a locations within a country. It was rare to find a document that addressed the topics of climate change and Caribbean biodiversity.
- There is a considerable body of knowledge and literature on Caribbean biodiversity, i.e., fauna, flora, vegetation, fungi. However, very little of the biodiversity information has been transferred to maps or geo-referenced databases. While reviewing the information available on the impacts of climate change on biodiversity in the Caribbean, a major gap in capacity was identified in the area designing and developing species and ecosystems models.
- Regarding terrestrial biodiversity, temperature will be an important controlling factor. Minimum temperatures are important for crops.
- Fire is a natural and anthropogenic impact on biodiversity. The frequency and extent of fires would be affected by changes in temperature and precipitation. The available information on fire for the region is limited and in many cases non-existent. It was also noted that fire would have implications for invasive species.

2.2.4 Protected area distribution and status

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

- The Conservation Action section found in the comprehensive summary on the Caribbean Islands as Biodiversity Hotspot (www.biodiversityhotspots.org, Conservation International, 2007a) covers a range of general regional issues such as the extension of the area land officially under conservation protection, and the Protocol Concerning Specially Protected Areas and Wildlife (SPAW) or the SPAW Protocol. The SPAW Protocol 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. The section also addresses national topics like the existence and effectiveness of protected areas. It is recognised that there is a great need for much better management, monitoring, and enforcement of protected areas throughout the Caribbean, and that the Caribbean Islands are named as top priority for the expansion of the global protected areas network (Conservation International, 2007a.)

2.2.5 Species distribution maps

- A search of the available literature did not indicate the existence of species distribution maps on a regional scale. Only in the case of the fungi were such regional maps available.
- Vegetation maps of the Caribbean islands, produced by The National Conservancy, are available (http://edcintl.cr.usgs.gov/tnc/products/atlas.html). Although these maps provide a potential source of spatial information on biodiversity distributions, the suitability of using these maps for modelling should still be checked, especially regarding the ground-truthing of the maps.
- Regarding habitat fragmentation, only the Cuban national map of vegetation fragmentation (Capote et al. 2005) has been found. Such maps are very useful for evaluating projected future impacts of climate change on biodiversity.

2.2.6 Maps of distribution of biodiversity hotspots

- A comprehensive summary addressing the Caribbean Islands as Biodiversity Hotspot is found trough the website of the organisation Conservation International (www.biodiversityhotspots.org, Conservation International, 2007a).

2.2.7 Data base

- A downloadable list (Species Database) of Vertebrate Species occurring in Caribbean Islands is available on the Conservation International Website. That 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 (Conservation International, 2007a).
- The Database of Fungi of the Caribbean is an annotated checklist with electronic distribution maps of Caribbean Fungi. www.biodiversity.ac.psiweb.com/caribmaps/index.htm. The database builds on the book by Minter et al. (2001), and resulted in 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 taxon recorded from the insular Caribbean.
- The Web page of the Cuban Clearing Housing Mechanism (CHM) has a major compilation of the 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 (CeNBio), which is based at the Institute of Ecology and Systematic (IES) 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).

2.2.8 Agro biodiversity

Agro biodiversity is one of the main manifestations of the interaction between people and nature. The diversity of animals and plants (e.g., those 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. As part of its National Biodiversity Strategy and Action Plan (https:/www.cbd.int/doc/world/cu/cu-nbsap-v2-es.pdf) Cuba has identified the following goals regarding agro biodiversity:

- to determine the priorities concerning agro biodiversity;
- to establish the National Network of Information on Agro biodiversity and to link it to the Cuban Clearing Housing Mechanism (CHM);
- to define indexes on agro biodiversity (www.ecosis.cu/chm/actividadeshabilitadoras.htm).

Genetic banks

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 programs, 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.

Citrus

Caribbean countries like Antigua, Bahamas, Cuba, Dominican Republic, Haiti, Trinidad and Tobago and Jamaica are incorporated to the Inter-American Citrus Network located in Cuba. The research on citrus in the region includes research on; phenology (Frómeta et al. 1985 a., 1985 b., 1990), on the influence of climatic factors on the external morphological characteristics of early oranges and on tropical citric phenology, and on bioclimatology as a tool for improving the cropping of citrus (Pérez et al., 2001, 2003). As all research indicates, citrus crops are highly sensitive to changes in temperature and rain regimes and the projected climate change.

Root crops: sweet potatoes, cassava, and potatoes

Root crops like cassava (*Manihot esculenta* Crantz), potatoes (*Solanum tuberosum* L.) and sweet potatoes (*Ipomoea batatas* L) play a significant role in the Caribbean food system. These crops contribute to the satisfaction of energy and nutritional requirements of our population. Several Caribbean islands have germoplasm collections for agricultural crops.

Current climate variability and projected climate change could negatively impact the productivity of these root crops. A summary of such negative impacts were published by Centella et al (2001), who modelled on potatoes and cassava production for the climatic projection of the HADCM2 model.

More information on the impacts of climate change on these root crops can be found at: http://www.ifpri.org/spanish/2020/briefs/br66sp.htm.

Rice

An alternative interesting approach to the relationship between rice crops and animal communities exists. Rice is sown in at least 4 island states in the Caribbean: Cuba, Dominican Republic, Haiti and Trinidad Tobago. Rice agro ecosystems can be understood as seasonal and temporal wetlands. They allow the persistence of animal communities typical to wetland areas (Martinez Vilalta, 1996).

From a conservation point of view, water birds are the most visible users of rice fields but not the only users. Other vertebrates like fishes, amphibians and reptiles (e.g., water snakes and turtles) also use the paddies. In addition, many invertebrates are found in paddies, e.g., annelids, molluscs, insects, crustaceans, zooplankton. Rice fields and the associated agricultural habitats (channels, parapets, and dikes) are used as foraging habitat by breeding, transient or wintering birds. To a much lesser extent, they function as nesting or resting habitats. From a conservation point of view, herons, egrets, ducks and shorebirds are the main group of water birds taking advantage of the rice system, but moorhens, gallinules, gulls and terns are also commonly found there (Mañosa 1992, Acosta 1998, Mugica 2000). The intensity of use of the fields and channels by water birds largely depends on the availability and proximity of alternative natural habitats. Rice fields provide an excellent substitution habitat that excels the quality of any other crop for water bird conservation.

In Cuba, 96 bird species have been reported using rice fields, 74% are considered migrant (37% winter migrants and 34% species with migrant and resident populations). In Trinidad Tobago, 73 bird species have been observed in the paddies. Taking into account that climate change may reduce coastal wetlands, water bird populations will be more dependent on rice farming. We need to be prepared for proposing future management measures.

2.3 A country by country assessment

A detailed country by country assessment has been prepared based on the on a review of publications, reports, studies, references and personal communications from the seven Caribbean countries (Antigua, Bahamas, Cuba, Haiti, Dominican Republic, Dominica and Jamaica) targeted in this assessment. The assessment focuses on the state of knowledge on biodiversity in the Caribbean, and it is based on reports and studies of national coverage, such as the country reports to the Convention on Biological Diversity.

2.3.1 Dominican Republic

Introduction

The website of the Convention of Biological Diversity (http://www.biodiv.org) has a page for Dominican Republic, which is a party of the Convention since November 1996. According to that page, the Dominican Republic is considered to have the highest diversity of ecosystems of the western hemisphere. The Dominican country has forests, savannahs, rivers, lagoons, sandy beaches, rocky coasts, wetlands, dunes, and mangrove swamps, all with high species diversity and genetic resources.

Current State of knowledge of biodiversity: Reports, papers, studies, and reports on biodiversity

A major overarching document is the “Diagnóstico: Situación Legal e Institucional de la Biodiversidad en República Dominicana” (República Dominicana, 2002b). The Diagnóstico, together with the document on the Vision for biodiversity for the year 2022 (República Dominicana, 2002a), was part of the process for achieving a Sectorial Law on Biodiversity in the Dominican Republic.

The Diagnosis includes statistics on biodiversity, e.g., at least 10% of species in the Dominican Republic, as well as 33% of vertebrates (mammals, birds, reptiles, amphibian and fishes) are threatened or endangered to extinction. A table on biodiversity at the species level reports number of species and endemic species of flora and fauna (when data are available). The numbers on flora are split into vascular plants (5600 species, 1800 endemics) and algae (168 species, unknown number of endemics). The numbers on fauna are split into mammals (48 species, 2 endemics), birds (296 and 26), amphibians (65 and 63), fishes (399 species), molluscs (311 species), arthropods/ crustaceans (164 species), cnidarians (111 species), echinoderms (67 species), sponges (39 species), and annelids (6 species). A table on threatened species addresses plants (5600 species; 442 threatened or endangered), algae (168; unknown number of threatened or endangered), vertebrates (954 and 204) and invertebrates (698 and 117) (República Dominicana, 2002b).

The Diagnóstico (República Dominicana, 2002b) also quotes references that seem to be very informative or data-rich on the topic of biodiversity, i.e., the environmental profile of the Dominican Republic (Dominican Republic, 2000) and an inventory of vegetation and land use in the Dominican Republic (Tolentino and Peña, 1998.)

The Vision for Biological Diversity for 2022 (República Dominicana, 2002a), intended to be a conceptual guide for defining and applying policies, plans, programs, projects and activities directed to ensure the conservation and sustainable use of biodiversity in the country. Also, the Vision was taken as the conceptual platform for elaborating a Sectorial Law on Biodiversity in the Dominican Republic.

The Proyecto de Ley Sectorial de Biodiversidad (República Dominicana, 2002c), which serves as a complement to the juridical issues that appear in the document, has six annexes that list: species endangered to extinction (around 35 species listed); threatened species (around 230 species listed); protected species (around 350 species listed); species of traditional use or used in sports (around 30 species listed); species with a commercial use (around 35 species listed); pest species (around 100 species listed). For each listed species, the corresponding annex includes taxonomic information on, the group (whether the species is a fish or a plant, etc.), the scientific name, family, common name,) and the status of the species in relation to endemism (e.g., endemic, native).

There is a high level of endemism with 53% of fish, 97% of amphibians, 83% of reptiles and 18% of birds endemic to the island. There are about 5,600 known plant species on the island, of which it is estimated that 36% are endemic. The protected areas cover around 20% of the total area. They include 13 national parks and 9 scientific reserves, five of which cover coastal and/or marine areas.

The Third National Report of the Dominican Republic to the Convention on Biological Diversity (República Dominicana, Tercer Informe Nacional) provides informative references. For instance, the Evaluación Ecorregional de la República Dominicana (2006) is noted to include analysis of maps of terrestrial, freshwater and marine biodiversity, and also the human activities and socioeconomic characteristics that can threaten the values of biodiversity.

The Third Report (República Dominicana, Tercer Informe Nacional), in one of its starting sections (page 4, Section: On priorities, goals, and obstacles), offers general characteristics of the country relevant for biodiversity (e.g., the wide range of climate and topographic conditions, reflected in the occurrence of 16 bioclimatic zones), and includes general figures. The report characterises the 48,198 km^2 country as having a unique and globally important biodiversity. The terrestrial biodiversity, which demonstrates 30% co-endemism with the biodiversity of Cuba, is estimated to number more that 7400 species. The projected endemism is around 33%. The

report notes that insects, algae, fungi, lichens and mosses have been poorly studied. That section of the report also highlights other current information, such as the importance of the waters off the Dominican Republic as a calving and nursery area whales in the Atlantic.

The document titled “Programa de Pequeños Subsidios” (República Dominicana, 2004), provides the strategic guidelines and the priorities for biodiversity conservation for the period 2004-2005. Some of the technical reports produced for the program, provide a useful source of information on impacts of climate change on biodiversity in the Dominican Republic. The document provides a general characterisation of the country, the national context and status of biodiversity and land degradation, greenhouse gas emissions, and international waters. The information provided and structure of the report corresponds to the topics relevant to the Fondo para el Medio Ambiente Mundial (FMAM). The FMAM serves as a permanent mechanism whose mission is the protection of the global environment through the financial support of programs and projects that provide global environmental benefits in priority thematic areas, i.e., biodiversity, climate change, international waters, and persistent organic pollutants, land degradation and integrated ecosystem management.

The document identified the Dominican Republic as a Caribbean country with high levels of endemism, and the second largest endowment of biodiversity. The document provides information on the number of species and the percentage of endemism for higher plants, birds, reptiles, amphibians and mammals. It provides short and informative insights on the recovery of natural forests in the humid zone through secondary succession once the rural population has abandoned agricultural areas and migrated to cities (República Dominicana, 2004).

In the last decade a slight improvement of the forest cover has been detected through the analysis of satellite images. The total arboreal cover of the country is 27% (13,226 km^2). Of that area over 40% is characterised as forest Of the forest cover, 47.5% (6,306 km^2) represents different categories of broad-leaf forest in humid and very humid zones, 27.7% (3,677 km^2) is dry forest, 22.8% (3,025 km^2) is conifer forests, and about 2% (257 km^2) is wetlands (República Dominicana, 2004).

Other topics covered in the report include the relation between the soil degradation in mountainous zones, salination in low zones of dry forests, the limited forest cover, and the misuse of irrigation waters. Erosion rate have been reported as being greater than 200

ton/ha/year, a major factor in the reduction of the operational life of the hydraulic infrastructures devoted to the storage of water for human consumption, energy generation and agriculture. The main water storage facilities can have sedimentation rates in excess of 3,188 m^3/km^2/year, which is 7.5 times the planned (projected) sedimentation (República Dominicana, 2004).

Vegetation maps and data bases

The main source of vegetation maps and databases is the Evaluación Ecorregional de la República Dominicana (2006). It is identified by República Dominicana (Tercer Informe Nacional) as including analysis of maps of terrestrial, freshwater and marine biodiversity, and also the human activities and socioeconomic characteristics that can threaten the values of biodiversity.

2.3.2 Antigua and Barbuda

Introduction

The total land area of Antigua is 280 sq. km. (108 sq. miles) while Barbuda is 160 sq. km (62 sq. miles). There are three topographic zones in Antigua; the southwest region is mountainous, the central plains are relatively flat and the north and east have limestone hills. The highest point in Antigua occurs at Boggy Peak, 402 m (1,319 ft.). Barbuda is flat with sand dunes. The highest elevation of 30.8m occurs at The Highland. Both Antigua and Barbuda experience a tropical marine climate with little variation in daily or seasonal temperatures. The annual temperature ranges from 22.4^{o}C to 30.5^{o}C, while relative humidity ranges from 72% to 85%. The drier cooler months are from January to April.

Rainfall was considered a very important climatic feature since its variability impacts on the availability of water. Droughts occur every few years in Antigua. Although not continuous, nor from the same location, rainfall data for Antigua dates back to 1874. Continuous records from the Meteorological Services at the VC Bird airport dates back to 1960. The average annual precipitation was approximately 1050 mm (40 ins.), although annual values range from 667 mm to 1708 mm. The flatter eastern and northern regions of Antigua are driest. Rainfall levels increase by 40% in the mountainous south-west region. Although the rainfall data for Barbuda is less comprehensive, it is significantly drier than Antigua due to the low topography. The average annual precipitation is 750 to 900 mm. (30 to 35 ins.)

There was a study of the soil resources by Martin-Kaye (1959). A comprehensive study of the soil resources of Antigua and Barbuda was conducted by the Regional Research Centre of the University of the West Indies in the early 1960's and mapped at 1:25,000 scale and published in 1966 (Hill 1966). Additional descriptions were added during the mid-1980's by Ahmad and published by the Organization of American States (OAS 1990) at 1:50,000.

Current State of knowledge of biodiversity: Reports, papers, studies, and reports on biodiversity

Studies of the flora have indicated that there are 149 families and 1158 species of plants in Antigua and Barbuda. There are 45 species of ferns and fern allies contained in 5 families. There are 3 families and 4 species of gymnosperms and 1109 species in 141 families of angiosperms. .

Two amphibians have been recorded. There are 20 reptile species of which 4 have gone extinct. There is a program to protect the Racer snakes (*Alsophis antiguae*). 182 species of birds have been recorded of which two-thirds are migratory; 20 are endemic to the sub-region. Codrington Lagoon has one of the most important colonies of Magnificent Frigate birds in the Caribbean. Bats are the only native terrestrial mammal of which there are 7 species. The Agouti is extinct. Fallow deer, Indian mongoose, rat, mouse are introduced. There is very little data on the invertebrates.

Regarding forest resources, most of the natural vegetation of Antigua was cut down to facilitate sugar cane production; while Barbuda retains much of its original forest. There are 5 major forest types: Humid Valley forest, Slope forest, Mangrove, Scleromorphic forest of white cedar, *Tabeluia pallida* and Mangrove edge. Humid valley forest is the most complex in Antigua; very little remains in the south-western volcanic region. Slope forest contains deciduous trees and is found in the Highlands of Barbuda and the southwestern volcanic region of Antigua. Morello (1983) indicates that much of this forest type has been altered due to charcoal production. There are three mangrove forest species. The scleromorphic forest exists only on Barbuda. Mangrove edge forest is chiefly found on Barbuda, it is dominated by Haematoxglon (logwood) and Pithecellobium ('bread and cheese').

Regarding agricultural activities, most lands are former sugar cane lands. Currently, sea-island cotton, Antiguan black pineapple, vegetables and livestock farming is practiced. The semi-

arid nature of the island is good for sea-island cotton, the major limitation is the need for manual harvesting. The Antigua black pineapple is limited by the availability of planting material.

The provision of seed for sea-island cotton is good. The provision for other crops is more limited. Much of the commercial vegetable germplasm was imported from North America and Europe. Some of these are no longer in production, but are still in use in Antigua and other Caribbean islands. Therefore, farmer saved seeds and vegetative plant material have been used to continue production. Diseases of root crops have forced changes to newer cultivars.

Because of the insularity of the islands, the plant genetic resources can remain genetically pure. There is no program specifically directed to germplasm evaluation and conservation in Antigua ad Barbuda. Some cotton germplasm is being maintained by the Ministry of Agriculture. The use of CSEGRIN (Caribbean Seed and Germplasm Resource Information Network) already set up through the FAO Improved Seed Project in CARICOM Countries and Surinam, would facilitate the development of a germplasm database.

In situ conservation of some plant genetic resources is done by CARDI, and seed laboratory exists at the CARDI field station. The Chemistry and Food Technology Division, Ministry of Agriculture of Antigua and Barbuda has created a list of plants traditionally used for medicinal purposes. The Environmental Awareness Group (EAG) in conjunction with the Nature Conservancy and Island Resources Foundation is running a project to survey selected habitats.

Antigua is the largest producer of vegetables per hectare in the OECS, this is due to the application of dry farming technologies such as drip irrigation and mulching. The dry conditions are good for the production of sea-island cotton, mauby (*Colubrina* sp.), pineapple, aloe, vegetables. The conditions are also good for forest products such as Citronella sp. mahogany for furniture and white cedar for boat building.
The high night temperatures in the ‘summer months’ May to September has affected vegetable crops in the area of fertilisation/ pollination; especially in tomatoes and head formation in cole crops such as cabbage and cauliflower. Changes in day length has affected pigeon peas and onions.

Although people engage in conservation and management of plant genetic resource for instance in Agriculture, Forestry, Horticulture, Soil Science, a more hands-on or practical

oriented approach is needed. In addition, the skills need to be spread and shared among more persons.

Vegetation maps and data bases

The obtained information does not explicitly indicate the availability of vegetation maps. Regarding databases, it was mentioned above that CSEGRIN (Caribbean Seed and Germplasm Resource Information Network), already set up through the FAO Improved Seed Project in CARICOM Countries and Surinam, would facilitate the development of a germplasm database.

2.3.3 Bahamas

Introduction

The Bahamas is located between latitude 20°.50'N and 27°.30'N and longitude 72° .35'W and 80°.30'W. The country is an archipelago of 700 islands and cays surrounded by coral reefs, wide-ranging sand flats and shallow waters. There are 254,000 residents the majority of whom live on New Providence. The total land area is 15 000 km^2 (5 792 mi^2).. The islands are low lying and relatively flat and composed entirely of calcium carbonate. Cat Island has the highest point in the entire archipelago, at 63 m (206 ft) above mean sea level (Dupuch, 2005).
Most rainfall occurs in the northern islands with approximately 1 470 mm (58 in) per annum. The southern islands receive the least amount of precipitation; approximately 865 mm (34 in). Rainiest months are May to June and September to October.

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Three forest types occur in the Bahamas, i.e., pine, coppice and mangrove. The northern Bahama Islands are dominated by forests of Caribbean pine (*Pinus caribaea* var. bahamensis). There are 46,800 hectares of pine forests in Andros, Abaco and Grand Bahamas in the northeast. The central and southern islands have been generally described as the coppice islands. Coppice is characterised by many valuable hardwood trees such as mahogany (*Swietenia mahagoni*), cedar (*Cedrela odorata*), mastic (*Mastichodendron foetidissimum*) and horseflesh (*Lysiloma sabicu*). Mangrove forest is found along the coastal areas of The Bahamas and in the inland wetlands and salinas.

Scrub exists in the extreme southeast. Ninety percent of the plant species of the Bahamas are endemic. 1350 species of flowering plants and ferns have been described these are contained in 660 genera and 144 families. The Bahamas is home to several rare and threatened species; these include the Bahamian Hutia and the Great Barn Owl. Populations of the West Indian Flamingo are recovering. There are 3 species of ground iguana.

Regarding agricultural activities, farming is done in the Family Islands; Abaco, Cat Island, Eleuthera, and Long Island. Southern islands generally have subsistence farming; while commercial farming occurs in the northern islands (Sealey, 1994). There are 1.3 million hectares of total land area of which 95,000 hectares is arable land. 7650 hectares is livestock or planted in crops. The chief crops are grapefruits, cucumbers, tomatoes, bananas, oranges, limes, watermelons and lemons.

There are 3 agricultural zones in the Bahamas; these differ based on rainfall precipitation and the availability of exploitable ground water. The southeast with rainfall less than 760mm per annum chiefly has subsistence agriculture using shifting cultivation practices. Only tried land races are used since rainfall is limited. Most farm operation is manual.

The central Bahamas has annual rainfall of 1000mm. Both subsistence and commercial agriculture practiced. There is some mechanisation of production but slash and burn is still practiced. Both commercial seed and land races are used; it is chiefly subsistence farmers who use land races.

The northern zone receives 15,000 mm of rain per annum and has large amounts of exploitable ground water. The land is flat, therefore agriculture is greatly mechanised. Nearly all export crops are grown in this region. Improved open pollinated and hybrid seed used to meet local and export market demand for consistency and quality. Very little land race seeds used. The commercial seeds require much fertilizer and chemical pest control unlike the land races.

There are 1371 varieties of Bahamian higher plants. 120 are endemic. Wild relatives of cultivated species of grapes, sweet potatoes and yams are on the list which is incomplete. There are no algae or fungi on the list. Regarding forests, the commercially important species is *Pinus caribaea* var. bahamensis found in the northern islands. The nature and diversity of the forests has not been described or catalogued. Coppice contains most genetic material for crop improvement, while the pine forests contain wild yams and grapes.

The land races provide a reservoir of well adapted but low yielding cultivars. Maize, sorghum, pigeon pea, okra, pepper and sesame are present. Vegetative propagated varieties of manioc, sweet potato, banana, eddoes and pineapples are present. There is no organised system of cataloguing and conserving the land races of traditional crops. They have been displaced in the northern islands and are at risk of being completely lost due to a lack of conservation practices and a decline in the numbers of subsistence farmers who are the chief users.

The Department of Agriculture maintains a small botanical collection of native and imported species. There is however no effort at directly protecting flora. No legislature exists that specifically addresses the conservation of plant genetic resources. Some conservation activities occur in the Bahamas. The Bahamas National Trust manages Exuma land and sea park on Exuma island; Flamingo National Park on Inagua; Village road Retreat on New Providence and Abaco Parrot Reserve on Abaco – this being 17,000 acres of mixed coastal coppice and pine forests. The area indirectly protects hardwoods, freshwater plant resources and the understory of northern pine forests.

All wild animals are protected – these include feral cats, dogs and pigs. The island has one National History Collection – the National Herbarium, which is managed by the Department of Agriculture. Additionally there are smaller collections at the Bahamas National Trust and the College of The Bahamas. There are private natural history collections of birds, butterflies and shells. Traditional skills and practices suitable to the local conditions, allow Family Islanders to produce crops under relatively harsh conditions, such as low rainfall and limited water supply, low soil nutrients, and a hot, marine climate. Future work shall address an inventory of genetic resources, and training of personnel involved in conservation activities.

Legal provisions relating to land management can be found in several pieces of legislation, e.g., Agriculture and Fisheries Act (1963), The Bahamas National Trust Act (1959), Land Surveyors Act (1975), Private Roads and Subdivisions Act (1961), Private Roads and Subdivisions (Outlands) Act (1965), Buildings Regulation Act (1971), Reclamation and Drainage Act (1916), Coast Protection Act (1968), Town Planning Act (1961), Conservation and Protection of the Physical Landscape of The Bahamas Act (1997), Water and Sewerage Corporation Act (1976), Environmental Health Services Act (1987) and Plants Protection Act (1916).

The Department of Agriculture oversees the agricultural provisions of the Agriculture and Fisheries Act (1963). This department works to stimulate and diversify crop production, and its mandate also includes the following responsibilities: hold, lease, manage and dispose of agricultural land; encourage agricultural development; provide and encourage scientific research in agriculture, conserve biodiversity and protect wild flora and fauna.

In April 2005, The Bahamas published its first state of the environment report, entitled "GEO Bahamas 2005", with technical and financial assistance from the Division of Early Warning Assessment of the United Nations Environment Programme (UNEP) (The Bahamas Environment, Science and Technology Commission, 2005).

A National Capacity Self-needs Assessment (NCSA) Project was conducted to determine the capacity needs of the country in 2003. Key gaps and deficiencies sited included: lack of legislation necessary to implement the environmental conventions; no official approval of existing environmental guidelines; non-existence of a department for the environment coupled with jurisdictional conflict and misunderstanding between various agencies with responsibilities relating to the environment; lack of financial and human resources; and insufficient services provided to the Family Islands (i.e., islands other than New Providence and Grand Bahama). Based on the findings from this project, it was recommended that the Government embark on establishing a national environmental management action plan.

As a result of the NCSA Project, it was apparent that a national environmental management action plan (NEMAP), designed to address the various findings from the project, was needed. The NEMAP will act as a mechanism for strengthening the legal, policy and institutional frameworks, with respect to environmental management. The action plan was developed with input from various stakeholders during a consultative workshop in 2005.

Vegetation maps. Data bases

The obtained information does not explicitly indicate the availability of vegetation maps. Regarding databases, a National Clearing-House Mechanism (CHM) for Biodiversity Information in the form of an interactive website (www.bahamaschm.org) exists. It is the goal of this national CHM website to allow for greater access and benefit-sharing of biodiversity data and information for users within The Bahamas and others throughout the world.

2.3.4 Dominica

Introduction

The Commonwealth of Dominica is located at 15º 30' North Latitude and 61º 25' and occurs between Guadeloupe and Martinique. It is the most northerly of the Windward Islands and has a total land area of 750.6km^2 (290 sq. miles).

Dominica's climate is humid tropical marine with average temperature 27ºC (80ºF). The average rainfall is 445 cm (175 ins) per year, most occurring in the wet season. Rainfall levels increase from the leeward side eastward to the central island where rainfall levels reach 1016 cm (400) inches annually.

Flat land is restricted to coastal areas in the northeast, in river valleys and in certain areas in the centre of the island. There is an extensive network of surface and underground water sources. The main river valleys are found in the centre of the island and include the Layou and Roseau on the leeward side, as well as the Clyde, Pagua, Castle Bruce and Rosalie valleys on the windward side.

Current State of knowledge of biodiversity: Reports, papers, studies, and reports on biodiversity

Dominica is characterised by very rugged and steep terrain. This mountainous topography has made it difficult to clear the lush vegetation. 65% of the land area is covered by natural vegetation. There are 7 – 9 plant communities recognised: Swamp forest (30 hectares), Littoral woodland (140 hectares), Dry scrubland (6240 hectares), Deciduous forest, Rainforests (24, 490 hectares), Montane rainforest (3640 hectares), Elfin woodland (170 hectares). Fumarole vegetation associated with geothermal areas is also present. Forests comprise 22.6% of the total land area while arable land is 27.8% of total land area.

The documentation of the flora is very comprehensive. The plant diversity has been estimated at 155 families, 672 genera and 1226 species of vascular plants. Several plant species are present and include the national flower Bwa Kwaib, *Sabinea carinalis*. Dominica has the most diverse avifauna of the Lesser Antilles. 175 species of birds have been recorded; many species are migratory, while 60 species breed on the island. Resident birds include two single island endemics and 9 regional endemic species. Small populations of seabirds are

concentrated on relatively inaccessible coastal cliffs. Eighteen species of mammals, 19 species of reptiles and 4 species of frogs have been recorded for Dominica. The invertebrate fauna has some gaps including an incomplete list of insects and the status of many species has not been determined. There are 11 species of freshwater shrimps, 20 species of semi-terrestrial crabs. There are 55 species of butterflies and 11 species of Phasmids recorded.

The chief agricultural crops are bananas, citrus, root crops, coconuts, plantain, beverage crops and cut flowers and livestock. Small farmers dominate and approximately 20% of the arable land is cultivated. The disease resistant properties of some plants are known, e.g., Jabba (*Xanthosoma* sp.), a wild type used as a source of animal food, is resistant to tannia burning disease.

Some important uses of wild plants are: food (Wawa, Mauby, Breadfruit, Breadnut, Babawle, Babadin, Mibi), industrial purposes (Screwpine, Larouman, Calabash, Bay leaf), medicine and other uses (Vanilla, Palmiste, Bwa Bande and Oucoo).

Non banana crops are affected by low yields. This has been attributed to poor marketing, variable weather and the poor quality of the planting material.
CARDI maintains a small micro-propagation centre in Dominica, including a field museum plot of 13 cultivars of yams at the Grand Bay Agricultural Station. These programmes are donor funded, so there is some risk that the germplasm may be lost when the funding ends. Very limited tissue culture activity is done on specific crops such as Anthuriums and tannia to provide planting material of new and improved cultivars through in vitro propagation. A geneplasm bank of passion fruit is also being maintained. CSEGRIN has been used – one yam cultivar has been characterised and evaluated.

One invasive plant is of particular concern, Lemon grass. It was introduced for oil production but it has spread over hundreds of acres of dry woodland and savannas. This is being blamed for a loss of biodiversity and land degradation.

Regarding conservation, The Forestry and Wildlife Act (1976) makes provision for wildlife management and protection in Dominica. The legislation is considered inadequate and the fines too low. The natural resources are not managed on a scientific basis and there is insufficient data on the sustainable exploitable levels of the resources. According to the Ministry of Agriculture (1996), 20% of forested land in Dominica is protected within forest reserves and

National Parks. There are two forest reserves: The Northern – 8,800 hectares and Central – 410 hectares. The Morne Trois Pitons National park is 6,872 hectares of legally protected forests in the south and centre of the island and includes the Archbold Reserve which is 380 hectares containing extensive areas of rainforests. There is also the Cabrits National Park. The Morne Diablotin National Park is proposed. It will be 8,525 acres containing primary forest especially elfin woodland and montane forest and the highest diversity of flora and fauna in the island.

Concerning future work, individuals need to be trained in taxonomy and farmers need training so that they could participate in a plant genetic resource inventory. There is need for training in seed science, germplasm, plant breeding, statistical sampling and social and anthropogenic studies. Laws are needed to regulate the planting of imported genetic material and sale and distribution of seeds. There is also need for Intellectual Property Rights legislature. The country has started the process of developing a National Environment Management Strategy (NEMS), which will serve as the major policy document guiding the management of the natural resource base. The Strategy will similarly identify the key issues and concerns with regard to the present management of the scarce natural resources including land.

Vegetation maps and databases

The information that was reviewed does not explicitly indicate the availability of vegetation maps and databases for Dominica.

2.3.5 Jamaica

Introduction

Jamaica is the 3rd largest island among the Greater Antilles. It is located approximately 18^{o} north and 78^{o} west. It is 236.4 km long and a maximum of 82 km wide with an area of 10962 km^2. There are 5 topographic divisions: The Blue Mountain Area, Central – Western Limestone Plateau, Central Inliers, Interior Valleys, and Coastal Plains.
More than 50% of the island is 300 m above sea level. The highest peak is in the east, the Blue Mountain Peak at 2,256 m. There is a central mountain range spanning the island from east to west, which includes the karstic Cockpit Country (Government of Jamaica, 1987).

The northern parts of the country are wetter than the south because easterly rains hit the north-eastern aspects of the Blue and John Crow Mountains, while cold fronts from North

America hit the north and central mountains, with very little carrying to the south coast (Jamaica Meteorological Service, 1973). There is bimodal pattern of rainfall in Jamaica, the heaviest showers occurring in October while the second maximum occurs in May (Jamaica Meteorological Service, 1973). The minimum rainfall occurs in March and June (GOJ, 1987). The mean annual rainfall is 1951 mm, although some areas in the Blue Mountains receive an average of 7500 mm of rain per annum (Jamaica Meteorological Service, 1973).

Sixty percent of the island's bedrock is white limestone, 25% is volcanic or Cretaceous, 10% is alluvial and 5% is yellow limestone (Porter, 1990).

Current State of knowledge of biodiversity: Reports, papers, studies, and reports on biodiversity

There are approximately 3,304 species of vascular plants in Jamaica; 923 are endemic and despite the numerous studies of the flora, new species are discovered with regularity. 60 species of bromeliads, 230 species of orchids, 579 species of ferns, 20 species of cacti, 10 palm species and approximately 200 species of grasses have been recorded.

Some forest types in Jamaica are: submontane tropical rainforest, montane rain and cloud forests on shale or volcanic rock; montane tropical or subtropical rainforest on limestone; lowland seasonal and semideciduous forest; grassland and marshy grassland.

Based on the assessment of forest cover conducted in 1998, 8% of the island's area is classified as closed broadleaved forest with minimal human disturbance. Most of the remaining 260,000 ha is classified as disturbed broadleaved forest or dry open forest, having varying degrees of human disturbance.

There are 211 species of rotifers, 562 species of land snails and slugs, 9 species of grapsid crabs, 26 species of jumping spiders, 48 species of fireflies, 133 species of butterflies, 59 species of ants, 22 amphibians, 43 reptiles, 39 shore and sea birds, 67 land birds and 21 species of bats recorded for Jamaica.

The habitat requirement of some species has been investigated. The loss of forest cover and the modification of forests have been shown to negatively affect some species. The Giant Swallowtail butterfly has been shown to have increased mortality due to increased parasitism in areas of high disturbance at the forest edge where they breed.

Approximately 30% of the endemic land birds rely on well developed forests for nesting while it is approximately 20% for non-endemic land birds. The Jamaican Hutia (*Geocapromys brownii*) requires forest cover for survival. The habitat requirements of organisms such as bats are as yet not well known.

The chief export crops grown in Jamaica are; sugar, banana, citrus, coffee, cocoa, spices. The production and processing of livestock products such a beef, poultry and dairy are well developed. Sectors that are developing include; bee farming and goat and pig rearing. Locally bred varieties of cattle are adapted to the climate, e.g., the Jamaica Hope, Jamaica Red and Jamaica Black. There are many small farmers who produce for the local market, and few large producers who produce for the export market.

Several botanical gardens have been established in Jamaica. The Bath Botanical Garden was set up in 1779. The supervisors were charged with collecting, classifying and describing the native plants. Several introduced plants were distributed from the garden. Castleton was established in 1860 when Bath Botanical Garden was unable to be expanded and was inundated with water. This property was 12 hectares and contained tropical plants and several mango grafts. Cinchona was set up as a 'hill-garden' to facilitate the introduction of European vegetables. Peruvian bark, coffee, tea and Cinchona were introduced. The methods for propagating, cultivating, harvesting and curing Cinchona were studied. Experimental plantations of oranges, forage plants and fibre plants such as China grass were set up.

Few tree crops and plants are native. They include pineapple, cassava, cedar, mahoe, mahogany and pimento. Most other crop plants were introduced, e.g., sugarcane, guinea grass, cinnamon, jackfruit, mango, yam, tobacco, ackee and coffee.

Research on the introductions of cultivars of grasses, evaluation of effect on livestock and data on establishment has been published. There are collections of pimento, ackee, cassava, avocado, mango, coconut, banana, citrus, cocoa and other root crops at museum orchards across the island. There is a limited amount of germplasm of guava, black pepper, annatto, naseberry, sour sop, breadfruit, corn and pigeon peas.

Conservation activities are not coordinated and there are mainly informal collections. A seed policy is being drafted.

Works done by UWI-Mona has produced strains or varieties grafted to retain genetic composition of parent stock. The Biotechnology Unit-UWI is actively engaged in tissue culture research. A Tissue Culture Unit was established with funding from the World Bank and the

Organization of American States (OAS) in 1982. It houses one of the largest in vitro germplasm collections of banana (Musa sp.) in the western world. Additional holdings of root crop varieties and fruit tree and ornamental plant varieties are also present.

Jamaica has one national park, the Blue and John Crow Mountain National Park, declared in 1993. Additionally, there are a few protected areas, e.g., Palisadoes- Port Royal protected area and Portland Bight. There are forest and game reserves which include the Cock pit Country. There is an ongoing project to assess protected areas and to develop a management plan.

In response to the increase in forest fires, the National Environment and Planning Agency (NEPA), in collaboration with the Forestry Department and the Jamaica Defence Force and Office of Disaster Preparedness and Emergency Management (ODPEM), have embarked on capacity building exercises with respect to wildfires and forest fire management.

NEPA and The Statistical Institute of Jamaica (STATIN) produces a biennial State of the Environment Report, the last being produced in 2001. The Jamaica National Environmental Action Plan (JaNEAP) is geared at national environmental management and identifying gaps and areas of future attention. Some goals of the National Biodiversity Strategy and Action Plan have adaptive value, these include:

Goal 1: Biodiversity Conservation: Establishment of a National Biodiversity Secretariat; Rehabilitation of Degraded Forests; Rehabilitation of Coral Reef Ecosystems; Preparation of an Alien Invasive Species Management Strategy; Implementation/preparation of recovery strategies for critically endangered species.

Goal 2: Sustainable Use of Biological Resources: Preparation of an Ecological Zonation Plan and Land Use Plans for Declared; Protected Areas; Development of a Sustainable, Community-based Management Plan for the Yallahs Lagoon Ecosystem.

Goal 3: Facilitation of Access to Biological Resources to Promote Developments in Biotechnology and Benefit Sharing: Preparation of policies and Legislation to facilitate access to biological resources and equitable benefit sharing; Creation of a Traditional Knowledge Register/Library.

Goal 4: Enhancement of resources management capacity: Expansion of the national Clearing-house Mechanism; Establishment of the Jamaica Protected Areas Biological Database.

Goal 5: Public Awareness and Education and Community Empowerment: Sensitisation of the judiciary and training for Customs and Immigration Officers and the Constabulary (Programmes

for the sensitisation of the judiciary, customs, immigration and constabulary have already been initiated).

Goal 6: Promotion of Local and Regional Cooperation and Collaboration in Implementing the Convention on Biological Diversity and the NBSAP: Building on existing regional data and information exchange mechanisms.

The Trees for Tomorrow Project (CIDA/GOJ) is focused on forest management and conservation and includes institutional development; it should result in land management and conservation of biodiversity. Assessment by the Forestry Department indicates that Jamaica has 30% forest cover (336,000 hectares). Loss of forest cover was estimate at 0.1% per annum for the period 1989 to 1998. 16.8% is undisturbed natural forest.

The Forest Act and regulations and the Watershed Management Act, now being revised, provide a framework that supports the policies and further strengthens the efforts to manage and rehabilitate watershed and forestry areas. Projects and programs to improve watershed management include: USAID/GOJ Ridge to Reef Project; GOJ Orchard Tree Crop Project; Rural agricultural extension services – including training for use of contouring, mixed cropping, integrated pest management and organic farming; and incentive programmes to encourage the involvement of private sector land owners.

The Forest Management and Conservation Fund was established in 1997 to provide long term funding for re-forestation and forest conservation. The Fund will be used exclusively for activities specified in the National Forest Management and Conservation Plan.

Planned activities include the development of: Management Plans for different parks and protected areas; Policy on Protected Animals in Captivity; Policy for Jamaica's System of Protected Areas; National Forestry Management and Conservation Plan; National Protected Areas System Plan; Giant Swallowtail Butterfly Recovery Plan; Iguana Conservation Strategy; Biodiversity Strategy and Action Plan, which seeks to implement and develop several projects, related to sustainable management of Jamaica’s biodiversity.

Vegetation maps and data bases

The information obtained does not explicitly indicate the availability of vegetation maps. Regarding databases, some of the topics addressed in the above quoted goals of the National Biodiversity Strategy and Action Plan regard databases, i.e., Goal 3 (Creation of a Traditional

Knowledge Register/Library); Goal 4 (Enhancement of resources management capacity: Expansion of the national Clearing-house Mechanism; Establishment of the Jamaica Protected Areas Biological Database); Goal 6 (Promotion of Local and Regional Cooperation and Collaboration in Implementing the Convention on Biological Diversity and the NBSAP: Building on existing regional data and information exchange mechanisms).

Also, NEPA (National Environment and Planning Agency) is currently conducting a biodiversity assessment of Jamaica to develop a database.

2.3.6 Haiti

Introduction

Haiti is a party of the Convention of Biological Diversity. Its National Biodiversity Strategy and Action Plan, and the First National Report (Republique d'Haïti, 1998), are available on the Convention on Biodiversity website (www.cbd.int/contries/country=ht) in English and French respectively.. That First National Report includes general characteristics of the country, some of which are also reported on the Convention's webpage for Haiti. The country has 27750 km^2, 1535 km of coastline and 5000 km2 of interior lands.

Current State of knowledge of biodiversity: Reports, papers, studies, and reports on biodiversity

The section Status and Trends of Biodiversity of Haiti's webpage on the Convention of Biological Diversity website, notes that in spite of severe environmental degradation, Haiti has, together with the Dominican Republic, the second most diverse flora in the Caribbean, after Cuba. Floristic studies among the vascular plants invariably reveal new species, particularly in biological rich areas. Scientists who conducted inventories of Haiti's flora have not reach a consensus on the number of existing vascular plant species. The number of those published in the literature ranges from 4,685 to 5,242. The report Flore d'Haiti suggests that over 5,365 vascular plant species are found in Haiti. It has been estimated that among these plants, 37% are endemic comprising approximately 300 species of Rubiaceae, 300 species of Orchidaceae, 330 species of Asteraceae, 300 Graminae and three species of Conifers (*Pinus occidentalis*, *Juniper juniperus*, *Juniperus ekmanii*). Overall, the Haitian landscape hosts, according to the Holdridge classification based on climate factors, a total of nine zones which supports the diversity of forest formations. The country boasts a rich fauna as well, with more than 2000

species of vertebrates of which 75% are considered endemic. The mainland and satellite islands reflect a high degree of endemism. A biological inventory of one offshore island, Navassa island (7 km^2), found more than 800 species, many of which may do not exist anywhere else in the world, and as many as 250 that might be entirely new to science.

Regarding the number and extent of protected areas, the webpage for Haiti on the Convention on Biodiversity website states that the Haitian Government has officially identified a total of 35 protected areas covering about 6% of the national territory. However, the percentage of effective protected areas is evaluated at no more than 0.3% of the overall surface of the country, leaving the Haitian Republic far behind other Caribbean countries, namely Jamaica (8.2%), the Bahamas (8.9%), Cuba (14.3%), the Dominican Republic (21.7%), Turk and Caicos (39.7%) and Martinique (66.3%).

Concerning the percentage of forest cover, the webpage addresses the main historical phases that have caused the decline form an historical level of forest cover of 90% in pre-Columbian times and 60% in 1923, to the recent assessments of true forest cover of only 1.5% of Haiti's land area. In 1990, only 600 km^2 were under dense forest cover, which represented only 4% of the original forest cover, or 2.2 percent of the land area.

Today only 338 km^2 are under dense forest cover (1.0%). Twenty percent, of the land area is under sylvopastoral conditions (grazed brush land and savannah), which is being constantly degraded as a result of overgrazing and lumber cutting for charcoal production.

The Haitian government has initiated a GEF Biodiversity Protection Enabling Activity to prepare a National Biodiversity Strategy and Action Plan (NBSAP) and establish a national Clearing House Mechanism. These initiatives are being undertaken with World Bank assistance. Five main priority areas covering a number of sectors of activity have been identified to address issues of sustainable management of biodiversity in Haiti. They are:

- Conservation of biological diversity;
- Education, and the identification and monitoring of biodiversity components;
- Sustainable use of components of biological biodiversity;
- Control of alien species and management of Genetically Modified Organisms;
- Set up a new legal, regulatory and institutional framework to manage Haitian biodiversity.

The webpage provides useful information under the headings Implementation of the Convention, Measures Taken to Achieve the 2010 Target, and Initiatives in Protected Areas.

The First National Report to the Convention on Biological Diversity (Republique d'Haïti, 1998) has a strong focus on the actions directed at that time to the objectives of the Convention, for instance a national initiative supported by the Ministry of Environment, the Plan of Action for the Environment, which proposed to several sectors measures focused on biodiversity, so that the actions to be implemented were focus on the preservation of ecosystems that are experiencing increasingly fragile due to overexploitation of natural resources. Those actions were also directed to the preservation of natural potentialities and to the enhancement of the quality of live of the human population.

2.3.7 Cuba

Introduction

Cuba has a large variety of ecosystems (42 types) and landscapes (23 types), ranging from arid and semiarid lands to humid tropical forests and mountains. Plains cover 75% of the territory, whereas mountains cover 18% and humid coastal lands cover the remaining 4%. Cuba is the main centre of evolution and speciation in the Antilles, and also one of the most important islands for biodiversity worldwide. Current Cuban vegetation is mainly formed by forests, thickets, herbaceous vegetation, vegetation complexes and secondary vegetation. The current forestall cover of the country has been estimated in 24.9% (Capote et al. 1989, 2005).

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The country has 6,519 species of vascular plants and an estimated of 26,953 animal species, mainly invertebrates, out of which 16,516 are described. Cuba also has a high level of endemism due to its extreme climate conditions, diversity of habitat, geologic evolution and geographic isolation. Because of this, approximately 50% of Cuban plants are endemics, and are 42% of the invertebrates and 32% of the vertebrates. The vertebrate endemics, out of a total of 612 vertebrate species, are: 15 mammals, 91 reptiles, 43 amphibians, 23 fish and 22 birds. Approximately 10% of the fauna and 2% of the vascular plants are considered threatened or endangered. As it has been happening in other developing countries, the biodiversity of Cuba

has been declining due to the modification of natural habitats (Convention on Biological Diversity, 2007).

The Institute of Ecology and Systematic (IES), and its National Centre for Biodiversity (CENBIO), are diagnosing all the available knowledge on flora and vegetation. The compilation process includes the information available on flora and vegetation, and on physical factor limiting the distribution of the terrestrial biodiversity. It also includes elaborating the vegetation map of Cuba (1/100,000) by regions, and the vegetation maps for coastal and rocky zones. With the collaboration of the National Museum of Natural History MNHN, CENBIO prepares the digital map of Samek´s phytogeographic districts based on geomorphological criterions. With other Cuban Institutions, IES collaborates on several biodiversity related actions, e.g., elaborating the list of exotic and introduced species (Francisco Cejas, Director National Centre for Biodiversity CeNBio, at IES).

Two of the major Cuban institutions working on terrestrial fauna (the Institute of Ecology and Systematic IES, and the National Museum of Natural History MNHN) are diagnosing the available knowledge on fauna, compiling all the available information and elaborating zoogeographic maps of Cuba. The compilation includes georeferencing the survey sites, for instance those reported in the zoological collections of both institutions. The working version of the database has 13 625 records (9918 for invertebrates, and 3707 for vertebrates). The invertebrates include the classes Insecta, Arachnida, and Nematoda. The vertebrates include birds, reptiles, amphibians, mammals and freshwater fishes. A database of 594 taxa used by the Cuban population was elaborated. Personal communication by Nereyda Mestre (Department of Invertebrate Zoology, Institute of Ecology and Systematic IES).

The Web page of the Cuban Clearing Housing Mechanism (CHM) has a major compilation of the 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 (CeNBio), which is based at the Institute of Ecology and Systematic (IES) 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) (Cuban Clearing Housing Mechanism CHM, 2007). The information also includes the:

- Diversity of the Cuban biota (2007); diversity and endemism of the Cuban terrestrial biota (2006); endangered species (2005).

- Lists of species of the Cuban flora, fauna and fungi. List of Cuban plant species used by the human population (2004).
- 75 databases of fauna, flora, fungi, and other topics related to biological diversity, including links to the corresponding institutions and/or administrators of the data bases.
- Cuban biological collections, including links to the institutions and/or administrators of the biological collections.
- Cuban institutions involved in research, conservation and management of the marine, coastal and terrestrial biological diversity.
- Cuban periodic publications on biological diversity.
- Cuban researchers in the field (not complete).
- Cuban bibliography on biological diversity (not complete).
- Cuban documents relevant to the Convention on Biological Diversity.

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The database *Fungi of the Caribbean. An annotated checklist* builds on the book by Minter et al. (2001), and resulted in 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 taxon recorded from the insular Caribbean.

Suárez et al. (2005), based on the works by Ferrás et al. (1999), and the aridity index developed by López (1998), obtained that the endemic plant species composition of six phytogeographic districts of eastern Cuba could be changed by the changes in temperature proposed in three General Circulation Models (GCM) for year 2100. The work suggests that analysing the vulnerability of the Cuban biodiversity to climate change should use the Ecologically Fragile Zones of Cuba proposed by Vales et al. (1998). The authors considered the development of the National System of Protected Areas as the most important adaptation action to preserve the Cuban biodiversity.

Ferrás et al. (1999) studied the relation between climatic variables and the floristic composition of the phytogeographic districts in Cuba by using Geographic Information Systems (GIS) and multivariate analysis. Rainfall and the aridity index had a negative correlation. The analysis of the mean changes in the temperature and rainfall regime given by General Circulation Models allowed predicting the possible variation in the composition of natural vegetation.

The realisation of the Cuban Country Study on Biodiversity (Vales et al., 1998) relates to Cuba's commitments as Signatory of the Convention on Biological Diversity. The Study contains the state of the art on the knowledge on biodiversity in Cuba. It assesses the biodiversity status, reports the current threats to the *in situ* preservation of biodiversity, considers the benefits of conservation management, and identifies needs for conservation. The main sections of the Study address: Socioeconomic factors that affect the Cuban biodiversity (e.g., demographic issues; human settlements; land use), Biological data (e.g., marine and terrestrial habitats, diversity of the Cuban biota; protected areas), Economic valuation and current expenses, and Institutional capacities (e.g., national legislation). The aims of the Study included setting the framework for the development of a Geographical Information System (GIS). The Study includes about 60 maps, 140 tables, and 40 figures.

The Cuban Country Study on Biodiversity (Vales et al., 1998) was complemented with the Cuban National Strategy and Action Plan for the Sustainable Use of Biological Diversity (Vilamajó et al., 2002), whose elaboration involved about 130 Cuban institutions and 260 specialists. The initial Action Plan for the short-, medium- and long-term had 134 actions related to topics like conservation and sustainable use of biodiversity; economic and social development, and territorial planning; and institutional strengthening. The updated Plan, i.e., for 2006/ 2010 (CITMA, 2006), has 91 actions for the period 2006/ 2010 and involves about 90 Cuban institutions.

The Vision of the Strategy states that it will contribute, through its actions and juridical planning, to the integration of environmental and development policies, so that the recognition of the value, use, wise management and conservation of biodiversity is strengthen, based on the fair distribution of the costs and benefits derived from the use of biodiversity (Vilamajó et al., 2002).

The Strategy proposed twelve Guiding Principles (e.g., the sustainable use of the components of biological diversity and the fair distribution of the costs and benefits derived from its use, are fundamental to a sustainable economic and social development). The Strategy has eleven main objectives related to topics like *ex situ* and *in situ* conservation, juridical planning, rehabilitation and restoration of degraded ecosystems, enhancement of the National System of Protected Areas, territorial planning, environmental education, social instruments and incentives, the environmentally safe use of biotechnology, and monitoring of biological diversity (Vilamajó et al., 2002).

In the Diagnosis section, the Strategy addresses the diversity of the Cuban biota, with sections devoted to the natural habitats and ecosystems (natural vegetation, marine habitats, Ecologically Fragile Zones), wild species (referring to the published Flora of Cuba, and monographic fauna studies), genetic resources, and traditional knowledge. Other issues are also addressed, for instance the processes that affect biological diversity (e.g., fragmentation or loss of habitat/ecosystem/landscape; species overexploitation; etc.); and instruments for conservation (e.g., institutional capacity and juridical capacities) (Vilamajó et al., 2002).

Habitat/ecosystem/landscape disruption, fragmentation or loss is the main cause of biodiversity loss. In 1959, the forest cover amounted to only 14% of the national territory. Thenceforth, up to 23.6% of forestland has been recovered (2004) (NCSA).
Capote et al. (2005) assessed patterns of ecosystem fragmentation at the national level by identifying the vegetation patches of the size classes: 0-10, 10-100, 100-1000, and larger than 1000 km^2. A national map of vegetation fragmentation was obtained, too. This work was motivated by the fact that fragmentation or loss of habitat/ecosystem /landscape is among the main processes affecting biological diversity in Cuba. The Cuban National Study on Biodiversity had identified habitat transformation, mainly related to deforestation and socioeconomic activities, as the main cause of biodiversity loss in Cuba (Vales et al., 1998; Vilamajó et al., 2002.)

The New Atlas of Cuba (IGACC-ICGC, 1989) includes 24 sections, and it is a characterisation of the Cuban natural and socioeconomic resources, their spatial distribution, their complexity and the expression of their territorial conditions. The Atlas comprises 627 maps of Cuba, the Caribbean and the rest of the world. Several maps address the distribution of biodiversity components, for instance those on flora and vegetation include issues like endemism, bioclimate (scale 1: 3000 000), current vegetation (1: 1000 000), original vegetation (1: 2000 000), and potential vegetation (1: 2000 000). Regarding Fauna, the maps include terrestrial faunal communities (1: 2000 000), ants, (1: 4000 000), terrestrial reptiles (1: 2000 000), endemic terrestrial mammals (1: 14000 000), and terrestrial molluscs (1: 13000 000). Other maps address topics highly relevant for the study of biodiversity, for example those maps on: Geophysical characteristics; Geology; Topography; Climate; Water resources; Sea; Landscapes; Population; and Industry.

The Sabana-Camagüey ecosystem is an archipelago in the northern central part of Cuba where tourism is the most important economic activity. The books (Alcolado et al., 1999, 2007) synthesise the results of more than thirteen years of research, based on an *ecosystem approach,* on the marine-coastal and terrestrial biodiversity of the archipelago. Biodiversity protection and conservation, and sustainable development, were addressed in the Sabana. Camagüey Project. The second book (Alcolado et al., 2007) analysed the implementation of Coastal Integrated Management in the archipelago; one of the chapters was devoted to an economical environmental evaluation of the ecosystem goods and services.

Mugica et al. (2005), in the first two chapters, give an overview on Cuban main wetlands and the general features of aquatic birds. The most important information that may be used to track future trends addresses the bird community associated to different Cuban wetlands. Relevant breeding information on Cuban water birds is also addressed, including main breeding sites, breeding periods for some colonial birds, colony size, and ecological aspects of breeding. The feeding ecology and food resources required by aquatic birds were studied, too. There is a chapter focused on birds in rice culture, an anthropic ecosystem that is heavily used by birds. Flooded rice fields provide foraging habitats for many breeding, and migrating species. The results presented show that in Cuba almost all common water birds are having a strong dependency of the paddies for their survival. The last chapter is focused on conservation and highlights the threats that are facing the aquatic birds and their environment and the Cuban efforts to preserve biodiversity from the national level to the local level, including several study cases.

Acosta and Mugica (2006) provide a 90-page monography that reviews the current knowledge on Cuban water birds. The document has a detailed analysis of the representation of the aquatic birds in Cuba, their distribution and abundance throughout the country. It gives information on the current status and ongoing research projects related to Cuban threatened aquatic birds. Also, it addressed the key breeding sites all over the country. The last part is dedicated to the conservation programs and institutions focus on research and conservation in Cuba. The appendix includes the list of all aquatic birds, their frequency, a general assessment of their abundance, the main wetlands and up to date information of the published papers in each wetland.

Coastal wetlands located landward to coastal mangroves, together with mangroves, are among the ecosystems most sensitive to sea level rise caused by climate change (Leda Menéndez, Senior Researcher at the Institute of Ecology and Systematic IES, personal

communication; Capote-Fuentes and Lewis, 2005, Capote and Menéndez 2006, Capote-Fuentes 2007, Fernández 2004, Menéndez and Guzmán 2006, Menéndez et al. 2000, Vales et al 1998). Such coastal wetlands include both herbaceous and forest wetlands. Together with mangroves, they have great importance in coastal ecology and protection (Betancourt 1972, Menéndez et al. 2000). Herbaceous and forest wetlands, typically developing in coastal freshwater environments, would be affected by the expectable increase in salinity related to sea level rise.

Coastal dunes and coastal karstic areas are sensible to sea level rise, too. Since their vegetation can naturally cope with relatively high salinity, sea level rise would mainly affect them via the induced flooding (Capote and Menéndez 2006, Fernández 2004, Menéndez and Guzmán 2006, Menéndez et al. 2000, Vales et al 1998).

Several biodiversity groups may be used as indicators of climate change. Regarding amphibians as indicator species for climate change, there is information available in Cuba (Rodriguez Schettino, 203; Diaz and Cadiz).

An indicator species is an organism whose characteristics (e.g., presence or absence, population density, reproductive success) are used as an index to measure for other species or environmental conditions of interest. The amphibians have several characteristics that make them more sensitive to environmental changes than other vertebrates, for instance:

- *The amphibious life cycle.* Most amphibians live both on land and in freshwater. This complex life pattern requires favourable conditions for the survival of amphibians in the water where they breed (i.e., where their eggs and larval develop), in their “home” land areas, and along their migratory pathways.

- *Absorptive surfaces.* All amphibians depend on skin respiration and dermal absorption of water. Their surfaces, including those of eggs and larvae, are permeable to gases and liquids. So, those surfaces are potential entries of chemical pollutants and pathogens coming from air, water, and terrestrial substrates.

- *Exposure to ultraviolet light.* Melanic pigments on the upper surfaces of the eggs and larvae protect the amphibians from damage by ultraviolet light at sensitive developmental stages. In clear shallow waters, especially at high elevations, such protection is particularly important. Post

metamorphic individuals living at high elevation are often heliothermic (basks in the heat of the sun, exposing themselves to direct sunlight for elevating the body temperature. Thus, many amphibians may be vulnerable to increased ultraviolet light levels due to thinning of the atmospheric ozone layer.

- *Food habits.* Most tadpoles forage extensively on plants and animal particles in the water, at the surface film, and in bottom muck. They also shred algae and other plant materials. Some persistent chlorinated chemicals “stick” to such particulate matter and accumulate at the water surface and in bottom sediments. Being fat soluble, they accumulate in fat deposits, and some residues may persist for the whole live of the animal. Amphibian larvae may be susceptible to the deleterious effects of such agents via ingestion and via their permeable gills and skin. After transformation from the larval stage, all amphibians feed entirely or almost entirely on animals, particularly invertebrates. Therefore, they are especially subjected to the bio magnification effects of persistent chemical contaminants in the food web.

- *Susceptibility to cold and drought.* As moisture-dependent ectotherms, amphibians are vulnerable to extremes of cold and dryness. Cold weather and/ or drought can prevent reproduction, sometimes for a number of years.

The book by Rodriguez Schettino (2003) offers comprehensive information on Cuban amphibians and reptiles. Also the handbook by Diaz and Cadiz (in press) is very comprehensive; it focuses on Cuban amphibians.

Both works include information on ecology, behaviour and distribution. Regarding butterflies (Insecta: Lepidoptera), climate change and habitat alteration may change species richness and community structure (Brown & Freitas, 2000). The presence of some diurnal or nocturnal butterfly species may be a good indicator of the status of an ecosystem and of its influence by physical variables. For example, some diurnal species of butterfly (e.g., subfamily Nymphalinae) disappear in anthropogenic environments when temperature is too high (Brown & Freitas, 2000). Other species (e.g., *Greta* spp, *Dismorphia* spp., *Anetia* spp.) are good indicators of forest conservation, as they are present only in very well preserved mountains (Alayo & Hernández, 1987; Brown & Freitas, 2000). Barro *et al.* (2004) found a high number of Cuban endemic Arctiidae that are exclusive to mountain ecosystems. The family Notodontidae is a good indicator of low scale affected environments (Summerville & Crist, 2002, 2003; Summerville *et al.*, 2004). Researchers from Havana University and the Institute of Ecology and Systematic are

currently working in a new version of the Atlas on Cuban butterflies. Also, experts at the National Museum of Natural History work on butterflies. A group of the Biology Department (University of the West Indies Mona Campus) have a large experience in Lepidotera biological studies, too.

The main articles and books on Cuban butterflies include those by Alayo and Hernández (1987), Alayo and Valdés (1982), Barro and Rodríguez (2004), Fontenla (2003), Núñez (2003), Núñez (2004), Torre (1967), Torre and Alayo (1959), Zayas (1989), Zayas and Alayo (1956), Alayo and Hernández (1987), Alayo and Valdés (1982), Barro et al (2004), Fontenla (2003), Núñez (2003), Núñez (2004), Torre (1967), Torre and Alayo (1959), Zayas (1989), Zayas and Alayo (1956).

In Cuba there is information on macro- and meso-fauna as bioindicators, particularly for agroecosystems. Soil fauna can be a good indicator of soil conditions. Most soil invertebrates are sedentary, and thus may reflect habitat conditions in relation to soil use and changes in its physical parameters (Paoletti *et al*., 1991; Stork and Eggleton, 1992).

For example, the conversion of forest into cultivated land causes exotic species to displace native land worms (Rodriguez 2000). Also, in agricultural lands the Colembola species typical to the superficial layers markedly decrease, while the characteristic species of the deepest soil layers increase (González *et al*., 2003).

The worm fauna in Cuba is represented by 51 species and 24 genera (41.6% genera and 60.7% species are native). These are among the highest values of both species and genus richness of the region. The diversity of the group and its high habitat specificity, together with the available knowledge, make the group a good indicator of environmental changes in soil parameters.

The team of Soil fauna at Havana University Faculty of Biology has studied the macro- and meso-fauna of natural and anthropic ecosystems during the last 25 years. The focus has been on Colembola, Acarinae, Oligochoeta, Diplopodae, and more recently on Quilopoda and Coleoptera. Besides describing the systematic of these groups in the soil, the team has discovered 3 new colembola species, one Acarinae, and 15 new species for science with 2 new worm genera of the Oligoqueta family. Another team, based at the Institute of Ecology and Systematic, has been studying the Cuban macro- and meso-fauna for more than 20 years too (see www.ecosis.cu/ies/ecologia.htm).

Important works on Cuban macro- and meso-fauna include those by Gil-Martín and Subías (1993), González et al (2003), Paoletti et al (1991), Rodríguez (2000), Fragoso et al (1999), González et al (2006), Rodríguez (1998, 2004), Rodríguez et al (1998, 2007), Rodríguez and Fragoso (1995, 2002, in press), Rodríguez and Rodríguez (2007).

Bird communities are sensitive to climate change. The Caribbean is home to over 560 species of birds. More than 25% of these species are endemic to the region and 56 are globally threatened. The Caribbean is also a critically important region for many Neotropical migrants. These species depend on the same wetland, forest and scrub habitats as resident and endemic species. Also, birds tend to be highly positioned in the food chain and thus may be particularly suitable as indicators of any signal in the food chain. The composition of the bird community is well known in the Caribbean islands. However, quantitative data are scarce for most ecosystems. Long term monitoring is scarce, too. Two main Cuban research groups have long experience in bird ecology and work in close cooperation. One group is based at the Institute of Ecology and Systematic, and is focused on bird banding and point counts of migrant forest birds in Cuban regions. The other group, based at Havana University Faculty of Biology, has been mainly working on the ecology of bird communities associated to rice culture and natural wetlands. In all cases, establishing long–term surveillance programs makes it possible to identify abnormal population changes. A good understanding of the ecology of the indicator species is necessary, too.

Important literature for Caribbean birds is included in Wunderle (2005). Concerning Cuba, the main literature produced by the group working at Havana University Faculty of Biology includes the works by Acosta and Mugica (1988, 2006), Mugica and Acosta (1989, 1992, 1994), Acosta et al (1994, 1992, 2002, 2003a, b), Denis et al (1999, 2005), Mugica et al (2001, 2003, 2006a,b). The main literature produced by the group based at the Institute of Ecology and Systematic includes the works by Balat and González (1982), Berovides et al (1982), Blanco et al (1994), Blanco (1992, 1995, 1996), Blanco et al (1992, 1993, 1995, 1996, 1997, 1998a, b, 1999a, b, 2001, 2002), Fernández et al. (1996), Garcia and González (1985), García et al (1986, 1987), Garrido and González (1980, 1999), Godinez et al (1994), González (1982a, b, 1988), González and González (1982), González et al (1986, 1987, 1989, 1990, 1992a, b, c, d, e, 1995, 1997, 2000, 2001, 2003), González and Garrido (1979), González and Llanes (1998, 2002), González and Sánchez (2002), González and Oviedo (1992), González (1991, 2001, 2002a, b), Goossen et al (1994), Kirckonnell et al. (1992), Latta et al. (2002,

2003), Mancipa et al (2000), Morton and González (1982), Mugica et al (2002), Peris et al (1995, 1998), Pozas and González (1984a, b), Rodríguez (2000, 2002a, b), Rodríguez et al (1989, 1990, 1991, 1994, 1996, 1997, 2003), Rodríguez and Sánchez (1988, 1989, 1993, 1995), Rodríguez and Acosta (1989), Rodríguez and García (1987), Sánchez and Rodríguez (1992a, b), Sánchez et al (1991, 1992, 1994, 2000, 2003), Wallace et al (1996), Wunderle et al (1992).

Regarding Fungi, an active and highly skilled group of Cuban mycologists works at Havana University Botanical Garden and the Institute of Ecology and Systematic. The group is focused on the protection of Cuban and Caribbean islands fungal biodiversity from impacts of climate change. The purpose of their research is to use the fungal communities as indicators of climate change and to provide proactive measures to conserve them.

Monitoring fungi populations is important for adapting to the projected climate change impacts on biodiversity. Most fungi are important for ecosystem health and stability. Some fungi are considered a pest. Due to climate change, fungi populations can increase or could be introduced and established (Mister et al 2001, Mena Portales et al., Distribution Maps of the Caribbean Fungi).

Cuba has a National System on Protected Areas (SNAP 2003-2008). The system aims, among other things, at covering at least 90% of all types of identified natural landscapes. The approval of the 201 Decree Law in 1999 is the most relevant measure taken by Cuba in order to legally establish a system or network of protected areas. The System includes 263 areas, 80 of which are of national importance and 183 are locally important**.** There are 8 Special Regions for Sustainable Development, which include 6 Biosphere Reserves, 6 Ramsar Sites and 2 Natural World Heritage Sites (CNAP, 2002; Convention on Biological Diversity, 2007).

Currently, 90 of the 263 Cuban proposed Protected Areas have some type of administration, 35 Protected Areas have been approved by the Cuban Government, 23 protected areas are in process. More than 15 areas are in the preparation process (CNAP 2002).

Developing training in all levels and components of the national system on protected areas is one of the strategic decisions of Cuba's SNAP. Taking into account other international methodologies, Cuba has developed, and is actively applying, a methodology to evaluate the effectiveness of protected area management (Convention on Biological Diversity, 2007.)

The Cuban National System of Protected Areas covers:

- 22 % of the national territory.
- 9 % of the territory under strict protection categories.
- 89 % of the plant autochthonous species; 85.3% of the endemic plant species; 77 % of the threatened plant species; 92.4 % of the native animal species and 96 % of endemic and threatened animal species. 100% of the migratory, native and endemic birds will be protected and all the high endemism hotspots of threatened vertebrates and other important areas for wildlife reproduction (CNAP 2002).

Regarding agro biodiversity Cuba has the following goals: to determine the priorities concerning that topic; to establish the National Network of Information on Agro biodiversity and to link it to the Cuban Clearing Housing Mechanism (CHM); to define indexes on agro biodiversity (Source: Conservation and sustainable use of biodiversity for agriculture) www.ecosis.cu/chm/actividadeshabilitadoras.htm.

Citrus

Cuba has a large experience on cropping and trading citrus. It is one of the preferred agricultural products for national consumption and also for exports.
The wide Cuban research on citrus made possible the chairmanship of the InterAmerican Network on Citrics (RIAC, in Spanish) to be located in Cuba. That research includes works on phenology (Frómeta et al. 1985 a., 1985 b., 1990), on the influence of climatic factors on the external morphological characteristics of early oranges and on tropical citrus phenology, and on bioclimatology as a tool for improving the cropping of citrus (Pérez et al., 2001, 2003).
The InterAmerican Network on Citrus (RIAC) is an organisation supported by FAO. It promotes and establishes technical and economic cooperation on citrus between countries of the American continent. That cooperation should mainly rely on the technical, human and financial resources of the countries. The Network also promotes the financial support by FAO, a Common Fund and other international organisations.

Rice

An alternative interesting approach to the relationship between rice crops and animal communities exists. Rice is sown in at least 4 countries in the Caribbean, i.e., Cuba, Dominican Republic, Haiti and Trinidad Tobago. Rice agro ecosystems can be understood as seasonal and

temporal wetlands. They allow the persistence of animal communities typical to wetland areas (Martinez Vilalta, 1996).

From a conservation point of view, water birds are the most apparent users of rice fields but not the only ones. Other vertebrates like fishes, amphibians and reptiles (e.g., water snakes and turtles) use the paddies, too. Also, many invertebrates are found in paddies, e.g., annelids, molluscs, insects, crustaceans, zooplankton. Rice fields and the associated agricultural habitats (channels, parapets, and dikes) are used as foraging habitat by breeding, transient or wintering birds. To a much lesser extent, they function as nesting or resting habitats. From a conservation point of view, herons, egrets, ducks and shorebirds are the main group of water birds taking advantage of the rice system, but moorhens, gallinules, gulls and terns are also commonly found there (Mañosa 1992, Acosta 1998, Mugica 2000). The intensity of use of the fields and channels by water birds largely depends on the availability and proximity of alternative natural habitats. Rice fields provide an excellent substitution habitat that excels the quality of any other crop for water bird conservation.

In Cuba, 96 bird species have been reported using rice fields, 74% are considered migrant (37% winter migrants and 34% species with migrant and resident populations). In Trinidad Tobago, 73 bird species have been observed in the paddies. Taking into account that climate change may reduce coastal wetlands, water bird populations will be more dependent on rice farming. We need to be prepared for proposing future management measures.

Root crops: yams, sweet potatoes, cassava and potatoes

Root crops like cassava (*Manihot esculenta* Crantz), potatoes (*Solanum tuberosum* L.) and sweet potatoes (*Ipomoea batatas* L) are very important to feed the Cuban and Caribbean population. There exists germplasm collection of these agricultural crops in Cuba. A summary of the impacts on potato and cassava production using the climatic projection of the HADCM2 model were published by Centella et al (2001). More information on root crops is available under http://www.ifpri.org/spanish/2020/briefs/br66sp.htm.

Scott *et al*. (2008) indicate that the most important root crops like cassava (*Manihot esculenta* Crantz), potato (*Solanum tuberosum* L.), sweet potato (*Ipomoea batatas* L.) and yam (*Dioscorea spp*) play a significant role in the global food system. These crops contribute to the energetic and nutritional requirements of more that 2000 million people in the developing

countries and would remain so in the next two decades. They are produced and consumed by the majority of the poorest and smallest farmers, who have the highest food insecurity.

Root crops are an important source of employment and revenues in the rural areas, including women. Also, these crops are adaptable to a wide range of uses, e.g., food security, basic food (for fresh and processed products), commercial crops, for animal food and as raw material for industrial purposes. Cassava, potato and sweet potato are among the main ten food crops produced in developing countries (http://www.ifpri.org/spanish/2020/briefs/br66sp.htm).

In Cuba there is a National Commission for Genetic Resources. It has sub commissions for phytogenetic and zoogenetic resources. It has also a National Network for Phylogenetic Resources. There is also the National Program of Science and Technique “Vegetal Improvement and phylogenetic resources”. That Program has the objective of conserving, using and improving the phytogenetic resources through increasing the collections of germplasm of species of current or potential economic importance. The Program also aims at developing new varieties of hybrids with advanced characteristics for contributing to sustainable development. Regarding citrus and Rutaceans, 41 forms of citrus have been prospected. The germplasm bank of citrus and other Rutaceans have more than 262 abcsesions.

More information on the phytogenetic and zoogenetic Cuban germoplasm collections is available at the *National Strategy for the Biological Diversity and Action Plan for the Republic of Cuba, 2002* and the Cuban CHM www.ecosis.cu/chm/chmcuba.htm.

Vegetation maps. Data bases

The Cuban Country Study on Biodiversity quoted: ¨*the first vegetation maps were made by Waibel (1943) and Canet (1946) (white and black maps at a small scale); by Alonso and Voronov (1970) and Areces (1978) (colour maps at small scales). The maps by Del Risco et al. (1977) and Oviedo and Del Risco (1993) (colour maps at medium scales) were already elaborated by applying remote sensing techniques, and according to the criteria of the international classification and vegetation cartography (UNESCO; 1973). Borhidi and Muñiz (1980) made a white and black map (1:3 500 000 scale). The Cuban vegetation map by Capote et al. (1989) is a colour one*¨. In the Cuban Country Study on Biodiversity (Vales et al. 1998), there is a vegetation map (1:1000 000 scale) and a description of the vegetal formations that

appear in its legend. Currently, there is a project for updating the Cuban vegetation map (1:100 000 scale), and for mapping the distribution of species. Another important map was obtained by Capote et al. (2005), i.e., the national map of vegetation fragmentation.

As mentioned in the above section of the present document, the Cuban Country Study on Biodiversity (Vales et al., 1998) includes about 60 maps. The Institute of Ecology and Systematic (IES), and its National Centre for Biodiversity (CeNBio), are diagnosing all the available knowledge on flora and vegetation, including maps. With the collaboration of the National Museum of Natural History MNHN, CeNBio currently prepares the digital map of Samek´s phytogeographic districts, based on geomorphological criteria.

The New Atlas of Cuba (IGACC-ICGC, 1989) includes 24 sections, and it is a characterisation of the Cuban natural and socioeconomic resources, their spatial distribution, their complexity and the expression of their territorial conditions. The Atlas comprises 627 maps of Cuba, the Caribbean and the rest of the world. Several maps address the distribution of biodiversity components (e.g., flora and vegetation include issues like endemism, bioclimate, current vegetation, original vegetation, and potential vegetation). Regarding Fauna, the maps include terrestrial faunal communities, ants, terrestrial reptiles, endemic terrestrial mammals, and terrestrial molluscs.

Several maps are also available for the Sabana-Camagüey ecosystem, an archipelago in the northern central part of Cuba where tourism is the most important economic activity (Alcolado et al., 1999, 2007). Acosta and Mugica (2006) provide a 90-page monography that reviews the current knowledge on Cuban waterbirds. The document has a detailed analysis of the representation of the aquatic birds in Cuba, their distribution and abundance throughout the country. Maps addressing the Cuban National System on Protected Areas (SNAP 2003-2008) are available, too (CNAP 2002).

Two of the major Cuban institutions working on terrestrial fauna (the Institute of Ecology and Systematic IES, and the National Museum of Natural History MNHN) are elaborating zoogeographic maps of Cuba, e.g., based on the zoological collections of both institutions. The working version of the database has 13 625 records (9918 for invertebrates, and 3707 for vertebrates).

As also mentioned in the above section of this document, the Web page of the Cuban Clearing Housing Mechanism (CHM) (www.ecosis.cu/chm/chmcuba.htm) 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) (Cuban Clearing Housing Mechanism CHM, 2007).

3. Knowledge Gaps Relating to the Impact of Climate Change on Terrestrial Biodiversity

3.1 Knowledge

- There was a frequent confusion between *biodiversity* and *wildlife*. Wildlife is an element of the CBD´s biodiversity concept, which includes all living organism, populations and *managed and non-managed* ecosystems.
- Information on the expected impacts of climate change on terrestrial biodiversity in the Caribbean islands was rather scarce and almost absent in the literature reviewed. Not much of the information can be found on cartographic products (i.e., maps).
- There is a marked fragmentation of the information on the regional biodiversity. The existence and location of the majority of the existing biodiversity information such as journals; books; reports; bibliographic and biological databases; maps; genes banks is commonly unknown. This situation also applies to the existing information resources on agro biodiversity, and human and institutional resources.
- There is absence of information on the effectiveness of protected areas under future climate change scenarios. Existing management plans for protected areas do not take climate change into account.
- The information on vegetation fragmentation for the region, and for many countries, is scarce.
- The documented information on the traditional knowledge of the biodiversity of significance to local and indigenous peoples is limited, dispersed and at risk of being lost. There is an urgent need to record the oral traditional knowledge.
- There is no standardised record of observations on transformations of phenology and behaviour of biodiversity.
- There is need for a data porthole through which data and information on the impact of CC on the regional biodiversity can be accessed. That facility shall be at least bilingual.

- A regional biodiversity databases should be established with data and information entries that are geo-referenced with an altitude component.
- There are some parameters, like soil moisture, for which there are no available climate change projections. These projections must be modelled and generated to support adaptation planning for biodiversity conservation and for strategically important economic sectors.
- Regarding invasive species, information and management experiences are fragmented in the region.
- There was a notable scarcity in the reviewed literature. of Caribbean studies on the impacts of climate change on phenological relationships in the region.
- The information on invasive and introduced species is scattered and in some cases incomplete. There is a lack of information on the response of invasive species to projected climate change for the region.

4. Research Agenda for Terrestrial Biodiversity

4.1 Guiding Principles

Five guiding principles were identified as key for the development of the research agenda on terrestrial biodiversity:

- All approaches to adaptation of biodiversity to climate change should consist of “win-win” strategies. Actions shall be oriented not only to allow biodiversity to adapt to projected climate change. Such actions shall also solve current environmental problems. An example of a win-win strategy is the protection or conservation of a species or ecosystem so that it can adapt to future impacts of projected changes in climate conditions, while also preserving the goods and services it currently provides to society.
- The impact of GCC on biodiversity will be assessed for natural, agricultural and modified ecosystems. Climate change will impact all biodiversity, in different ways, and with different intensities. Impacts will not be limited to wildlife but will also affect to domesticated species.
- The preservation of biodiversity, so that it can adapt to climate change, should occur not only in protected areas but also outside of the protected areas.

- The analysis of climate change impacts on terrestrial biodiversity should incorporate socio-economic impacts like population pressure and economic pressures on land use intensity, and incomplete legal framework for biodiversity protection.
- Any research project for the region should include training and capacity building activities to increase the capacity of local human resources and to support institutional development.

4.2 Research activities

The following is a list of the research activities that were identified as priorities:

- Completion of species and vegetation databases, especially for taxonomic groups and vegetation types that are sensitive to climate change. All new databases should be geo-referenced, including the altitude as a variable.
- When possible, the existing databases should be subjected to a geo-referencing process and should include the altitude as a variable.
- Completion of species and vegetation distribution maps at regional and national level.
- Completion of habitat fragmentation maps for each island.
- Habitat fragmentation assessment and modelling of future status.
- Completion of the information on invasive and introduced species and their impact under projected climate conditions.
- Vulnerability assessment (landscapes, ecosystems, habitats, species groups, and species).
- Assessment at the regional and national levels of the vulnerability of protected areas to climate change. The purpose would be identifying impacts and threats, and developing of protected areas systems resilient to climate change, as well as adaptation plans.
- Completion of the information on traditional knowledge of biodiversity, including, agro-biodiversity that is significant to local and indigenous peoples.
- Phenological studies of the biodiversity to detect the evidence of climate change impacts on species and biological relationships.
- Impacts on biodiversity using models (e.g., on species, groups, and ecosystems) which shall use as inputs the changes in meteorological variables projected by GCM models. Another alternative method to be considered is to accumulate map-based information and to use combinations of overlays as queries to identify areas of special interest, and then to downscale to such areas the projection of meteorological variables projected by the GCM models outputs. This would allow the specialists to interpret what is plausible or not for the species, group or ecosystem.

5. Institutional Capacity

5.1 Research Institutes working on Climate Change

Belize

Caribbean Community Centre for Climate Change

Cuba

Central Station for Research on Coffee and Cacao (ECICC)

Centre for Coastal Ecosystem Research (CIEC)

Centre for Environmental Studies and Services of de Pinar del Rio (ECOVIDA)

Centre for Fishery Research (CIP)

Centre for Marine Research (CIM)

Eastern Centre for Biodiversity and Ecosystems (BIOECO)

Institute for Animal Science (INCA)

Institute for Experiments on Pastures and Forages “INDIO HATUEY”

Institute for Fundamental Research on Tropical Agriculture “Alejandro de Humboldt” (INIFAT)

Institute for Horticulture Research “Liliana Dimitrova” (IIHLD)

Institute for Research on Rice

Institute for Research on Tropical Viands (INIVIT)

Institute of Ecology and Systematic (IES)

Institute of Forestry Research (IIF)

Institute of Meteorology (INSMET)

Institute of Research on Pastures and Forages (IIPF)

Institute of Research on Tropical Fruit Growing (IIFT)

National Botanical Garden (JBN)

National Centre for Animal Health (CENSA)

National Centre for Biodiversity (CeNBio)

National Centre for Protected Areas (CNAP)

National Institute for Plant Health (INISAV)

University of Havana University Faculty of Biology

Puerto Rico

Institute of Forestry

Jamaica.and Barbados

University of the West Indies. Climate Change Centre, and Mona Campus,
Caribbean Data Management Centre, Discovery Bay

5.2 Existing and needed capacities

5.2.1 Data collection and monitoring

There are some capacities in the region for biological data gathering, although neither equally developed in all the countries nor available for all the taxa. Many scientists from outside of the Caribbean region have participated in the development of biodiversity inventories. There is a need for the enhancing of the local capacities for collecting biodiversity data. Institutional support is needed to guarantee the collection of data over long periods of time for the long-term monitoring of the impacts of climate change on biodiversity.

5.2.2 Database and information management

Biodiversity databases have been identified in a few of the countries assessed in the preparation of this report. Future studies should continue with the identification and evaluation of existing biodiversity databases in the Caribbean. Attempts should be made to standardise existing and future databases to ensure a uniform structure to facilitate sharing, exchange, and use of biodiversity data at the regional level.

A network of the existing biodiversity clearing house mechanisms or a regional clearing house mechanism could be configured to provide information services such as: A database or directory of institutions of the Caribbean islands with biodiversity related mandates by country and thematic area (e.g., research; administration/regulation; enforcement; management/ conservation and training/education).

- Available information from regional projects related to biodiversity and/or climate or links for accessing such information.
- Mechanisms for accessing literature (peer reviewed journals, books, and data) (e.g., through on-line access to scientific literature for low GDP countries www. oaresciences.org).

5.2.3 Biodiversity modelling

The national and regional capacities are almost non-existing. These capacities must be developed if the research on the impacts of projected climate change on the region's biodiversity is to be undertaken to provide useful information for adaptation planning. It should be developed in order to do the research needed on projections of climate change in the region.

There exists the need to develop a Caribbean information network. The network would collect and bring together the information or links to the information on Caribbean institutions working on climate change and biodiversity. It would also provide information on the publications or models relevant to the impacts of climate change on biodiversity. Similarly, publications (journals, books and reports) on Caribbean biodiversity, databases, maps and regional climatic information relevant to climate change, would be included too. A directory of Caribbean islands researchers on biodiversity (including agro biodiversity) and climate would be useful, including information on location (country/institution); functional title; qualification; contact information; specialisation and areas of research interest/knowledge (e.g., similar to www.whoiswho.sidsnet.org).

6. Recommendations

- The ecosystem approach should be applied to future researches on the impact of climate change on biodiversity.
- All future biodiversity researches should incorporate protocols in order to geo-reference (including the altitude) the information about the various levels of biodiversity.
- There is a need to create an adequate mechanism for the coordination and creation of capacities to develop models and scenarios and to adapt to eventual climate change impacts on biodiversity at both a national and regional levels.
- To create a Caribbean information network on biodiversity and climate change. The network would collect and bring together the available information or to provide links to information on institutions, publications, databases, maps, and researchers relevant to climate change and biodiversity in the Caribbean.
- To use the protected areas as climatic and biodiversity monitoring areas for detecting the biological evidence of climate change impacts.
- Mona Geo-informatics, based at the Mona Campus of the University of the West Indies, was identified as wanting to participate in a project where they can apply their expertise in GIS

mapping. A collaborative arrangement with Mona Geo-informatics would help to address the need to geo-reference and map biodiversity information on regional and national scales.

- Some species, groups of species and formations of terrestrial biodiversity will be more susceptible to the projected climate change impacts. Their study should be a priority. For instance:
    - Groups: Amphibians, Lepidoptera (butterflies), Birds, Soil fauna.(Personal communication Dr. Lourdes Mujica)
    - Terrestrial vegetation formations like wetlands (e.g., herbaceous and forest wetlands, and mangroves); coastal vegetation (e.g., coastal dunes, coastal karstic areas) including those located landward to coastline mangroves; high elevation vegetation (dependent on temperature); highly fragmented ecosystems.(Personal communication Dr. Daysi Vilamajo, Dr. Leda Menendez and Dr. Rene P. Capote).

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In a section (page 10) related to the 2010 Goals, that reference is quoted by República Dominicana (No year specified) as including the analysis of maps of terrestrial, freshwater and marine biodiversity, and also the human activities and socioeconomic characteristics that can threaten the values of biodiversity.

Reference: Perfil Ambiental de la República Dominicana 2000. (In other documents, this reference has been found reported for 2001 instead of 2000). That reference should not be confused with: Ingeniería Civil y del Medio Ambiente, S. A. 2001. Perfil Ambiental de la República Dominicana. Ing. Roberto Castillo Tió, Consultor en Medio Ambiente. Santo Domingo, D.N., 160 pp.

The document seems to be very informative or data-rich on the topic of biodiversity. It is quoted in documents like the 2002's Diagnóstico: Situación Legal e Institucional de la Biodiversidad en República Dominicana (República Dominicana, 2002, see summary below), and in the 2002's La Diversidad Biológica en la República Dominicana: Visión para el año 2022 (República Dominicana, 2002a, see summary below).

Reference: República Dominicana. 2002a. La Diversidad Biológica en la República Dominicana: Visión para el año 2022. Secretaría de Estado de Medio Ambiente y Recursos Naturales. Santo Domingo, República Dominicana, 13 pp.

The elaboration of that document was coordinated by International Resources Group, IRG. with the sponsoring of the USAID as part of the project Asistencia a la Secretaría de Estado de Medio Ambiente y Recursos Naturales. The Vision on the Dominican biodiversity for the year 2022 is that its different components (genes, species and ecosystems) are sustainably used. Such use is based on the knowledge of the potential of biodiversity for contributing to the national development. Using biodiversity includes preserving and protecting species and habitats in an efficient juridical and institutional framework, and with the participation of the sectors involved.

The document expresses the perception of several sectors about the situation desired for biodiversity in the Dominican Republic for the year 2022. The document is intended as a conceptual guide for defining and applying policies, plans, programs, projects and activities directed to ensure the conservation and sustainable use of biodiversity in the country. The Vision was the result of two workshops, where several sectors participated.

These sectors had a concern or were affected by the situation of the non-human inhabitants of the island, including the fact that such part of biodiversity forms the core of the economic support of many people. Besides the general vision for biodiversity for the year 2022, the document includes specific visions for five major components or action lines: habitat conservation; genetic resources; conservation of threatened species; use of biodiversity; and control of alien species. It was stressed the need to take all the country sectors as components of only one socio-political-economic structure, i.e., the Dominican Republic.

The Vision was taken as the conceptual platform for elaborating a Sectorial Law on Biodiversity in the Dominican Republic. The elaboration of that law is a mandate of the General

Law on Environment and Natural Resources, No. 18, of August 18, 2000. The Sectorial Law is intended to be the juridical instrument that guides the actions on the topic, not only for the government and the ministry of environment and natural resources but for all the society. Thus, the law on biodiversity is expected to be the best way of ensuring the long-term viability of the populations of above 7000 known species of flora and fauna in the country.

Reference: República Dominicana. 2002. Diagnóstico: Situación Legal e Institucional de la Biodiversidad en República Dominicana. Secretaría de Estado de Medio Ambiente y Recursos Naturales. SantoDomingo, República Dominicana, 23 pp.

The elaboration of that document was coordinated by International Resources Group, IRG with the sponsoring of the USAID as part of the project Asistencia a la Secretaría de Estado de Medio Ambiente y Recursos Naturales. The present document, together with another document addressing the Vision for biodiversity for the year 2022, was part of the process for achieving a Sectorial Law on Biodiversity in the Dominican Republic.

The diagnosis aims to offer a picture of the juridical and institutional situation of the biodiversity issue. The document takes into account the biodiversity in the Dominican Republic; the juridical situation of biodiversity; and the institutional limitations and opportunities for achieving a law on biodiversity. The diagnosis is mainly based on a review of the current legislation, the Environmental Profile of the Dominican Republic of year 2000, and on opinions given by key interviewed informants.

The document includes numbers on biodiversity, e.g., at least 10% of species in the Dominican Republic, as well as 33% of vertebrates (mammals, birds, reptiles, amphibian and fishes) are threatened or endangered to extinction. A table on biodiversity at the species level reports number of species and endemic species of flora and fauna (when data are available). The numbers on flora are split into vascular plants (5600 species, 1800 endemics) and algae (168 species, unknown number of endemics). The numbers on fauna are split into mammals (48 species, 2 endemics), birds (296 and 26), amphibians (65 and 63), fishes (399 species), mollusks (311 species), arthopods/ crustaceans (164 species), cnidarians (111 species), echinoderms (67 species), sponges (39 species), and annelids (6 species). A table on threatened species addresses plants (5600 species; 442 threatened or endangered), algae (168; unknown number of threatened or endangered), vertebrates (954 and 204) and invertebrates (698 and 117.)

The document quotes references that seem to be very informative or data-rich on the topic of biodiversity:

Perfil Ambiental de la República Dominicana 2000. (In other documents, this reference has been found reported for 2001 instead of 2000).

Tolentino, L., and M. Peña. 1998. Inventario de la vegetación y uso de la tierra en la República Dominicana. Departamento de Inventario de Recursos Naturales, Sub-Secretaría de Recursos Naturales, Secretaría de Estado de Agricultura (SEA).

Reference: República Dominicana. 2002b. Proyecto de Ley Sectorial de Biodiversidad. SantoDomingo, República Dominicana, 69 pp.

As a complement to the juridical issues that appear in the document, it has six annexes that list: species endangered to extinction (around 35 species listed); threatened species (around 230 species listed); protected species (around 350 species listed); species of traditional use or used in sports (around 30 species listed); species with a commercial use (around 35 species listed); pest species (around 100 species listed).

In the corresponding annex, species endangered to extinction are defined by the law as those species whose populations' viability, the reproductive capacity or the genetic diversity have been reduced to levels critical for survival. Threatened species are those whose populations have been significantly reduced. Protected species are those whose populations are unknown or that are not suitable to be used because no use has been developed. Species of traditional use or used in sports are those whose populations allow a sustainable non-commercial use. Species with a commercial use are those that are valuable for food, forestry or commercial use, and whose populations allow such use in a sustainable way. Pest species are those exotic or native species that are affecting the equilibrium of natural ecosystems or that are causing damage in artificial ecosystems.

At least in the preliminary version of the law (i.e., the one quoted here), the annexes were given three months as a period to be checked up towards achieving their final version. A future update after 2 years was conceived, too. For each listed species, the corresponding annex includes taxonomic information like group (whether the species is a fish or a plant, etc.), scientific name, family, common name,), and related also the status of the species in relation to endemism (e.g., endemic, native).

Reference: República Dominicana. 2004. Programa de Pequeños Subsidios. Estrategia Nacional Revisada. Segunda Fase Operativa. Programa de Pequeños Subsidios (PPS) del Fondo para el Medio Ambiente Mundial (FMAM), Programa de las Naciones Unidas para el Desarrollo (PNUD).

Although this document is devoted to the strategic guidelines and the priorities of the Program for 2004-2005, it points out the Program (e.g., some of its technical reports), as a promising source of information on impacts of climate change. The document includes some numbers for a general characterisation of the country, especially in the document's section II on the national context, which has sections on biodiversity and land degradation, emissions on greenhouse gases, and international waters. The sections, and the information provided, correspond to the topics relevant to the FMAM as a permanent mechanism whose mission is the protection of the global environment through the financial support of programs and projects that provide global environmental benefits in priority topics, i.e., biodiversity, climate change, international waters, and persistent organic pollutants, land degradation and integrated ecosystem management. The document declares that the country has 48,442 km2 and over 8.5 million people. The maximum distances are: 390 Km East-West, and 265 Km North-South. The coastline has about 1,550 Km. It is the broadest island of the Greater Antilles, and the one with the highest elevation, i.e., Pico Duarte (3,175 m). Although different ecosystems are found, the dry forests, humid forest, and very humid forests cover more than 82% of the country.

The document states that the country is considered the second country in the Caribbean with the largest biodiversity, which has a high endemism. There are more than 6500 species of higher plants (36% of endemism), 296 bird species (9% of endemism), 146 reptile species (94.5% of endemism), 65 species of amphibians (100% of endemism), and 32 mammal species (10% of endemism).

The document provides short but also informative insights, for instance the recovery of natural forests in the humid zone through secondary succession, once the rural population has abandoned agricultural areas and migrated to cities.

A slight improvement of the forest cover has been noticed in the last decade in some forest ecosystems, as it is evidenced by the analysis of satellite images. The total arboreal cover

of the country is 27% (13,226 Km2). Of that cover, the forest cover is over 40%. Of the forest cover, 47.5% (6,306 Km2) refers to different categories of broad-leaf forest in humid and very humid zones, 27.7% (3,677 Km2) is dry forest, 22.8% (3,025 Km2) is conifer forests, and about 2% (257 Km2) is wetlands.

Other topics include the relation between the soil degradation in mountainous zones, salination in low zones of dry forests, the insufficient forest cover, and the wrong use of irrigation waters. Erosion rate can be greater than 200 ton/ha/year, a major cause in the reduction of the life-time of the hydraulic infrastructures devoted to the storage of water for human consumption, energy generation and agriculture. The main water deposits can have sedimentation rates over 3,188 m3/km2/year, which is 7.5 times the planned (projected) sedimentation.

Reference: República Dominicana. (No year specified). Tercer informe nacional a la Conferencia de las Partes, Convención de Diversidad Biológica. República Dominicana; Secretaría de Estado de Medio Ambiente y Recursos Naturales; Subsecretaría de Estado de Áreas Protegidas y Biodiversidad. 146 pp.

The Report includes the contact information of the corresponding national contact institutions, including persons. The Report, on page 3 (Section: On the preparation of the Report), refers the documents and webpages on which the Report was based. Two references, not checked for this review but whose titles make them to appear very informative, are:

Estadísticas Ambientales de América Latina y el Caribe. 2004. Caso-República Dominicana. Secretaría de Estado de Medio Ambiente y Recursos Naturales.

Evaluación Ecorregional de la República Dominicana. (Borrador). 2006. Proceso de formulación de políticas para la gestión del Sistema Nacional de Áreas Protegidas (SINAP) The Nature Conservancy.

Regarding that last reference, in a section (page 10) related to the 2010 Goals, it is stated that such Evaluación Ecoregional de la República Dominicana includes analysing maps of terrestrial, freshwater and marine biodiversity, and also the human activities and socioeconomic characteristics that can threaten the values of biodiversity.

Other programs and projects mentioned relate to the “Programa de Áreas Importantes para la Conservación de las Aves –AICA-, started by BirdLife Internacional (organisation previously known as Consejo Internacional para la Preservación de las Aves CIPA). BirdLife Internacional is worldwide engaged in bird conservation. The Program was extended into Dominican Republic

since 2002 with the support of the MacArthur Foundation for the implementation of the Project "Conservación de la Biodiversidad en el Caribe Insular: canalizando sitios de acción a través de colaboración local, nacional y regional". In order to go ahead with the Program, since 2003 the Project "Conservación Sostenible de Habitats Caribeños de Importancia Global para las Aves: Fortaleciendo una red regional de un uso compartido" was started, funded by the Fondo para el Medio Ambiente Mundial (FMAM) through the Programa de Naciones Unidas para el Medio Ambienten (PNUMA). This program is coordinated by the el Grupo Jaragua Inc.
Other references found in the Report are: Ley General de Medio Ambiente y Recursos Naturales (Ley 64-00), Anteproyecto de Ley Sectorial de Áreas Protegidas y Biodiversidad (already checked for this Review), the "La Biodiversidad en la República Dominicana, Visión para el año 2025" (already checked for this Review). The web pages quoted in the Report are those of the Secretaría de Estado de Agricultura (www.agricultura.gov.do/default.htm), and that of the Secretaría de Estado de Medio Ambiente y Recursos Naturales (www.ceiba.gov.do/2004/index_esp.html), the Boletín Jaragua Informa, 2005. Grupo Jaragua, Inc. (www.grupojaragua.org.do) and the Listin Diario Digital (www.listin.com.do).

In another starting section (page 4, Section: On priorities, goals, and obstacles), the format of the Report asks for the status, situation and tendencies of the components of biodiversity in the country. The corresponding 1-page information concentrates on general characteristics of the country relevant for biodiversity (e.g., the wide range of climate and topographic conditions, reflected in the occurrence of 16 bioclimatic zones), and includes general figures. The country, with 48,198 km^2, is considered to have a unique and globally important biodiversity. The terrestrial biodiversity, which shares a 30% of co-endemism with Cuba, is estimated in more that 7400 species. The projected endemism is around 33%. Insects, algae, fungi, "lichens" and mosses have been poorly studied. The amphibians and reptiles respectively have 97% and 94% of endemism. Regarding birds, 30 species are endemic. That section of the Report highlights other punctual information, for instance the importance of the Dominican Republic for the reproduction of whales in the Atlantic.

Reference: Tolentino, L., and Peña, M. 1998. Inventario de la vegetación y uso de la tierra en la República Dominicana. Departamento de Inventario de Recursos Naturales, Sub-Secretaría de Recursos Naturales, Secretaría de Estado de Agricultura (SEA). In: República Dominicana. 2002. Diagnóstico: Situación Legal e Institucional de la Biodiversidad en República Dominicana. Secretaría de Estado de Medio Ambiente y Recursos Naturales. Santo Domingo, República Dominicana, 23 pp.

From its quotation in República Dominicana (2002), the document by Tolentino and Peña (1998) seems to be very informative or data-rich on the topic of biodiversity.

Dominican Republic: List of References

Evaluación Ecorregional de la República Dominicana. (Borrador). 2006. Proceso de formulación de políticas para la gestión del Sistema Nacional de Áreas Protegidas (SINAP) The Nature Conservancy. In: República Dominicana. (No year specified). Tercer informe nacional a la Conferencia de las Partes, Convención de Diversidad Biológica. República Dominicana; Secretaría de Estado de Medio Ambiente y Recursos Naturales; Subsecretaría de Estado de Áreas Protegidas y Biodiversidad. 146 pp.

Perfil Ambiental de la República Dominicana 2000. (In other documents, this reference has been found reported for 2001 instead of 2000). That reference should not be confused with: Ingeniería Civil y del Medio Ambiente, S. A. 2001. Perfil Ambiental de la República Dominicana. Ing. Roberto Castillo Tió, Consultor en Medio Ambiente. Santo Domingo, D.N., 160 pp.

República Dominicana. 2002a. La Diversidad Biológica en la República Dominicana: Visión para el año 2022. Secretaría de Estado de Medio Ambiente y Recursos Naturales. SantoDomingo, República Dominicana, 13 pp.

República Dominicana. 2002b. Diagnóstico: Situación Legal e Institucional de la Biodiversidad en República Dominicana. Secretaría de Estado de Medio Ambiente y Recursos Naturales. Santo Domingo, República Dominicana, 23 pp.

República Dominicana. 2002c. Proyecto de Ley Sectorial de Biodiversidad. SantoDomingo, República Dominicana, 69 pp.

República Dominicana. 2004. Programa de Pequeños Subsidios. Estrategia Nacional Revisada. Segunda Fase Operativa. Programa de Pequeños Subsidios (PPS) del Fondo para el Medio Ambiente Mundial (FMAM), Programa de las Naciones Unidas para el Desarrollo (PNUD).

República Dominicana. Tercer informe nacional a la Conferencia de las Partes, Convención de Diversidad Biológica. República Dominicana; Secretaría de Estado de Medio Ambiente y Recursos Naturales; Subsecretaría de Estado de Áreas Protegidas y Biodiversidad. 146 pp.

Tolentino, L., and Peña, M. 1998. Inventario de la vegetación y uso de la tierra en la República Dominicana. Departamento de Inventario de Recursos Naturales, Sub-Secretaría de Recursos Naturales, Secretaría de Estado de Agricultura (SEA).

Antigua and Barbuda: References with available detailed summaries

Summaries not available (see references below).

Antigua and Barbuda: List of References

Grant, Lesroy C. 1995. Antigua and Barbuda: country report to the FAO international technical conference on plant genetic resources.

Hill I. D. 1966. Soil and Land Use Surveys, No. 19A & 19B: Antigua and Barbuda, Regional Research Centre, University of the West Indies, 59 pp plus maps.

Martin-Kaye, P. 1959. Reports on the geology of the Leeward and British Virgin Islands.

Morello, J. 1983. Ecological diagnosis of Antigua and Barbuda. Organization of American States, Dept., Reg. Dev., Washington, D.C.

OAS. 1990. Natural resources assessment, application and projects for the agricultural sector of Antigua and Barbuda. Organization of American States (OAS). Dept. Reg. Dev., Washington, D.C.

United Nations Convention to Combat Desertification. 2005. Draft national action plan for Antigua & Barbuda. Compiled by: The Technical Advisory Committee, for The Environment Division Ministry of Public Works and Environment. April, 2005.

Bahamas: References with available detailed summaries

Summaries not available (see references below).

Bahamas: List of References

Bahamas: country report to the FAO international technical conference on plant genetic resources (Leipzig, 1996) Prepared by: Simeon Pinder, Abaco, June 1995.

Sealey, Neil. 1994. *Bahamian Landscapes: An Introduction to the Geography of The Bahamas*. 2nd Edition. Media Publishing, Nassau, The Bahamas.

The Bahamas Environment, Science and Technology Commission. 2005. GEO Bahamas 2005: State of the Environment. NAPCO Printing, Nassau, The Bahamas.

The Commonwealth of the Bahamas First national report on the implementation of the United nations convention to combat desertification. The Bahamas Environment, Science and Technology Commission. Ministry of Energy and Environment. August 2006.

Dominica: References with available detailed summaries

Summaries not available (see references below).

Dominica: List of References

Dominica: country report to the FAO International Technical Conference on plant genetic resources, Leipzig, 1996. Prepared by: Ministry of Agriculture, Roseau, June 1995

Dominica's Biodiversity Strategy and Action Plan 2001 – 2005.

The Commonwealth of Dominica July 2002. The Commonwealth of Dominica's Second National Report on the Implementation of the United Nations Convention to Combat Desertification.

Jamaica: References with available detailed summaries

Summaries not available (see references below).

Jamaica: List of References

JAMAICA FAO COUNTRY REPORT (no date or author data but the document is very current).

Ministry of Agriculture and Mining. 1995. Jamaica: Country report to the FAO International Technical Conference on plant genetic resources (Leipzig, 1996).

Ministry of Land and Environment. 2003. Jamaica National Assessment Report: A Ten Year Review of the Implementation of the 1994 Barbados Programme of Action for the Sustainable Development of Small Island Developing States.

National Environment and Planning Agency. 2003. National Strategy and Action Plan on biological diversity in Jamaica.

Haiti: References with available detailed summaries

Summaries not available (see references below).

Haiti: List of References

Republique d'Haïti. 1998. First National Report. Implantation de la Convention sur Diversté Biologique en Haití. Intérimaire a la Quatrième Conférence Parties. Ministere de L'Environnement. 5 pp.

Convention on Biological Diversity. 2007. Website of the Convention. (http://www.biodiv.org). Webpage on Haiti.

Cuba: References with available detailed summaries

Minter, D.W., Rodríguez Hernández, M., Mena Portales, J. 2001. *Fungi of the Caribbean, An Annotated Checklist*. UK, London, Isleworth; PDMS Publishing. With 11,268 fungi species from all the Caribbean Islands, 946 pp. Database Fungi of the Caribbean. An annotated checklist. With electronic Distribution Maps of Caribbean Fungi. www.biodiversity.ac.psiweb.com/caribmaps/index.htm.

The database *Fungi of the Caribbean. An annotated checklist* builds on the book by Minter et al. (2001), and resulted in 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 taxon recorded from the insular Caribbean.

Reference: Suárez, A.G., López, A., Ferras, H., Chamizo, A., Vilamajó, D., Martell, A., Mojena, E. 1999. Sector Biodiversidad y Vida Silvestre. (Wild Life and Biodiversity). In: Gutierrez, T., Centella, A., Limia, M., and López, M. (Editors). *Impactos del Cambio Climático y Medidas de Adaptación en Cuba (Climate Change Impact and Adaptation. Cuban Country Study)*. Project No. FP/CP/2200-97-12, United Nations Environmental Program (UNEP), INSMET (Institute of Meteorology), La Habana, Cuba, 164-178 pp.

Based on the works by Ferrás et al (1999) and the aridity index developed by López (1998), the authors obtained that the endemic plant species composition of six phytogeographic districts of eastern Cuba could be changed by the changes in temperature proposed in three General Circulation Models (GCM) for year 2100. The present work suggests that analysing the

vulnerability of the Cuban biodiversity to climate change should use the Ecologically Fragile Zones of Cuba proposed by Vales et al. (1998). The authors considered the development of the National System of Protected Areas as the most important adaptation action to preserve the Cuban biodiversity. A summary of the results obtained were published by Centella et al. (2001).

Ferrás, H., López, A., Martell, A., and Suárez, A. G. 1999. Relaciones de la diversidad en la flora endémica cubana con la vegetación y la aridez del clima. II Estudio de las variables climáticas. *Acta Botánica Cubana*, No. 136.

López, A. 1998. Algunas características del endemismo en la flora de Cuba Oriental. . En: Halfffter, G. (ed) *La Diversidad Biológica en Iberoamérica II.* Volumen Especial. Acta Zoológica Mexicana, nueva serie. 47-82. Instituto de Ecología A.C. Xalapa. México

Centella, A, Llanes J., and Paz, L. (Editors). 2001. *República de Cuba. Primera Comunicación Nacional a la Convención Marco de Naciones Unidas sobre el Cambio Climático*. La Habana, 169 p.

Reference: Ferrás, H., López, A., Martell, A., and Suárez, A. G. 1999. Relaciones de la diversidad en la flora endémica cubana con la vegetación y la aridez del clima. II Estudio de las variables climáticas. *Acta Botánica Cubana*, No. 136.

The relation between climatic variables and the floristic composition of the phytogeographic districts in Cuba was studied by using Geographic Information Systems (GIS) and multivariate analysis. Rainfall and the aridity index have a negative correlation. The analysis of the mean changes in the temperature and rainfall regime given by General Circulation Models allowed predicting the possible variation in the composition of natural vegetation.

Reference: Capote, R.P., Guzmán, J.M. and Llamacho, J. 2005. Fragmentación de vegetación en el archipiélago cubano: conservación de diversidad biológica y mitigación de cambios globales en áreas protegidas. Proyecto Nacional del Programa Nacional de Cambios Globales, República de Cuba. In: *CD Proceedings V Conference on Environment and Development*. Havana, Cuba.

Previous to this work, the Cuban National Study on Biodiversity had identified habitat transformation, mainly related to deforestation and socioeconomic activities, as the main cause

of biodiversity loss in Cuba. Fragmentation or loss of habitat/ecosystem/landscape is among the main processes affecting biological diversity in Cuba (Vales et al., 1998; Vilamajó et al., 2002).

The present work assessed patterns of ecosystem fragmentation at the national level by identifying the vegetation patches of the size classes: 0-10, 10-100, 100-1000, and larger than 1000 km^2. A national map of vegetation fragmentation was obtained. The analysis was based on a digital version of the Map of Current Vegetation of the Cuban Archipelago (1:1 00 0000) (Capote et al., 1988), published in the New Atlas of Cuba (IGACC-ICGC, 1989). The sugar cane industry was the main source of destruction of Cuban original forests due to its demand for wood as fuel (Herrera et al., 1988). Wetlands, specifically herbaceous wetlands and mangroves, are among the natural vegetation formations having more numerous and largest fragments. They are also among the main core areas of the National System of Protected Areas (CNAP, 2002).

Capote, R.P., N.E.Ricardo, A.V.González, E.E.García, D.Vilamajó and J.Urbino. 1989. Vegetación Actual. 1: 000 000. X.1.2-3. En: IGACC-ICGC. *Nuevo Atlas Nacional de Cuba*. Ediciones Alber, España. Instituto de Geografía de la Academia de Ciencias de Cuba (IGACC), Instituto Cubano de Geodesia y Cartografía (ICGC), 226 pp.

CNAP. 2002. *Sistema Nacional de Áreas Protegidas. Cuba. Plan 2003-2008*. CNAP/ CITMA/ GEF/ PNUD. 22 pp.

Herrera, R.A., Menéndez, L., Rodríguez M.E., and García, E.E. 1988. Historia del uso de las tierras en Sierra del Rosario. In: Herrera, R.A., Menéndez, L., Rodríguez, M.E., and García, E.E. (Editors). *Ecología de los bosques siempreverdes de la Sierra del Rosario*. Proyecto MAB No. 1, 1974-1987. pp. 1-32.

IGACC-ICGC. 1989. *Nuevo Atlas Nacional de Cuba*. Ediciones Alber, España. Instituto de Geografía de la Academia de Ciencias de Cuba (IGACC), Instituto Cubano de Geodesia y Cartografía (ICGC), 226 pp.

Vales, M., Alvarez, A., Montes, L. and Ávila A. (Comp.) 1998. *Estudio Nacional sobre la Diversidad Biológica en la República de Cuba*. United Nations Environmental Program (UNEP), Centro Nacional de Biodiversidad (CeNBio) at the Instituto de Ecología y Sistemática (IES), Ministerio de Ciencia, Tecnología y Medio Ambiente (CITMA), 480 pp.

Vilamajó, D., Vales, M., Capote, R.P. and Salabarría, D. 2002. *Estrategia Nacional y Plan de Acción para el Uso Sostenible de la Diversidad Biológica*. United Nations Environmental Program (UNEP), Centro Nacional de Biodiversidad (CeNBio) at the Instituto de Ecología y Sistemática (IES), Agencia de Medio Ambiente (AMA), Ministerio de Ciencia, Tecnología y Medio Ambiente (CITMA). Available in the website of the Convention on Biological Diversity http://www.biodiv.org.

Reference: Vales, M., Alvarez, A., Montes, L. and Ávila A. (Comp.) 1998. *Estudio Nacional sobre la Diversidad Biológica en la República de Cuba*. United Nations Environmental Program (UNEP), Centro Nacional de Biodiversidad (CeNBio) at the Instituto de Ecología y Sistemática (IES), Ministerio de Ciencia, Tecnología y Medio Ambiente (CITMA), 480 pp.

The realisation of Cuba's Country Study on Biodiversity relates to Cuba's commitments as Signatory of the Convention on Biological Diversity. The Study contains the state of the art on the knowledge on biodiversity in Cuba. It was conducted together by institutions and specialists from a wide range of sectors. It assesses the biodiversity status, reports the current threats to the *in situ* preservation of biodiversity, considers the benefits of conservation management, and identifies needs for conservation. The main sections of the Study address: Socioeconomic factors that affect the Cuban biodiversity (e.g., demographic issues; human settlements; land use), Biological data (e.g., marine and terrestrial habitats, diversity of the Cuban biota; protected areas), Economic valuation and current expenses, and Institutional capacities (e.g., national legislation). The aims of the Study included setting the framework for the development of a Geographical Information System (GIS). The Study includes about 60 maps, 140 tables, and 40 figures.

Reference: Vilamajó, D., Vales, M., Capote, R.P. and Salabarría, D. 2002. *Estrategia Nacional y Plan de Acción para el Uso Sostenible de la Diversidad Biológica*. United Nations Environmental Programme (UNEP), Centro Nacional de Biodiversidad (CeNBio) at the Instituto de Ecología y Sistemática (IES), Agencia de Medio Ambiente (AMA), Ministerio de Ciencia, Tecnología y Medio Ambiente (CITMA). Available in the website of the Convention on Biological Diversity http://www.biodiv.org.

The Cuban National Strategy and Action Plan for the Sustainable Use of Biological Diversity is the second phase of the Cuban National Study on Biological Diversity. The elaboration of these two documents relate to Cuba's commitments as Signatory of the

Convention on Biological Diversity. The process towards the elaboration of the document involved about 130 Cuban institutions and 260 specialists. The Strategy was complemented with an Action Plan for the short-, medium- and long-term. That Plan has 134 actions related to topics like conservation and sustainable use of biodiversity; economic and social development, and territorial planning; and institutional strengthening.

The vision of the Strategy states that it will contribute, through its actions and juridical planning, to the integration of environmental and development policies, so that the recognition of the value, use, wise management and conservation of biodiversity is strengthen, based on the fair distribution of the costs and benefits derived from the use of biodiversity. The Strategy proposed twelve Guiding Principles (e.g., the sustainable use of the components of biological diversity and the fair distribution of the costs and benefits derived from its use, are fundamental to a sustainable economic and social development). The Strategy has eleven main objectives related to topics like *ex situ* and *in situ* conservation, juridical planning, rehabilitation and restoration of degraded ecosystems, enhancement of the National System of Protected Areas, territorial planning, environmental education, social instruments and incentives, the environmentally safe use of biotechnology, and monitoring of biological diversity.
In the Diagnosis section, the Strategy addresses the diversity of the Cuban biota, with sections devoted to the natural habitats and ecosystems (natural vegetation, marine habitats, Ecologically Fragile Zones), wild species (referring to the published Flora of Cuba, and monographic fauna studies), genetic resources, and traditional knowledge. Other issues are also addressed, for instance the processes that affect biological diversity (e.g., fragmentation or loss of habitat/ecosystem/landscape; species overexploitation; etc.); and instruments for conservation (e.g., institutional capacity and juridical capacities).

The Strategy identifies five work priorities (e.g., to keep and increase the capturing of the existing information on biodiversity, so that decision-makers can rely on more useful, efficient and updated information). The Strategy also proposes fourteen work topics (e.g., to assess the efficiency of the National System of Protected Areas for biodiversity protection.)

Reference: CITMA. 2006. *Plan de Acción Nacional 2006/ 2010 sobre la Diversidad Biológica*. Republic of Cuba. Ministerio de Ciencia, Tecnología y Medio Ambiente (CITMA). 64 pp.

The Action Plan of the Cuban National Strategy for the Sustainable Use of Biological Diversity (see reference Vilamajó et al., 2002) was conceived to be regularly updated, and so did CITMA

(2006). The updated Plan has 91 actions for the period 2006/ 2010; about 90 Cuban institutions are involved.

Reference: IGACC-ICGC. 1989. *Nuevo Atlas Nacional de Cuba*. Ediciones Alber, España. Instituto de Geografía de la Academia de Ciencias de Cuba (IGACC), Instituto Cubano de Geodesia y Cartografía (ICGC), 226 pp.

The Atlas includes 24 sections, and it is a characterisation of the Cuban natural and socioeconomic resources, their spatial distribution, their complexity and the expression of their territorial conditions. The Atlas comprises 627 maps of Cuba, the Caribbean and the rest of the world. Several maps address the distribution of biodiversity components, for instance those on flora and vegetation include issues like endemism, bioclimate (scale 1: 3000 000), current vegetation (1: 1000 000), original vegetation (1: 2000 000), and potential vegetation (1: 2000 000). Regarding Fauna, the maps include terrestrial faunal communities (1: 2000 000), ants, (1: 4000 000), terrestrial reptiles (1: 2000 000), endemic terrestrial mammals (1: 14000 000), and terrestrial mollusks (1: 13000 000). Other maps address topics highly relevant for the study of biodiversity, for example those maps on: Geophysical characteristics; Geology; Topography; Climate; Hydric resources; Sea; Landscapes; Population; and Industry.

Reference: The Web page of the Cuban Clearing Housing Mechanism (CHM) has a major compilation of the 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 Center for Biodiversity (CeNBio), which is based at the Institute of Ecology and Systematic (IES) in Havana. The information available on the webpage includes the:

- Diversity of the Cuban biota (2007); diversity and endemism of the Cuban terrestrial biota (2006); endangered species (2005).
- Lists of species of the Cuban flora, fauna and fungi. List of Cuban plant species used by the human population (2004).
- 75 data bases of fauna, flora, fungi, and other topics related to biological diversity, including links to the corresponding institutions and/or administrators of the data bases.
- Cuban biological collections, including links to the institutions and/or administrators of the biological collections.
- Cuban institutions involved in research, conservation and management of the marine, coastal and terrestrial biological diversity.

- Cuban periodic publications on biological diversity.
- Cuban researchers in the field (not complete).
- Cuban bibliography on biological diversity (not complete).
- Cuban documents relevant to the Convention on Biological Diversity.

References: Alcolado, P.M., García, E.E., and Espinosa, N. (Editors). 1999. *Protección de la Biodiversidad y Desarrollo Sostenible en el Ecosistema Sabana-Camagüey*. (Protecting Biodiversity and Establishing Sustainable Development in the Sabana-Camagüey Ecosystem). Proyecto GEF/PNUD Sabana-Camagüey CUB/92/G31. CESYTA S.L. Madrid, 145 pp.

Alcolado, P.M., García, E.E., and Arellano-Acosta, M. (Editors). 2007. *Ecosistema Sabana-Camagüey. Estado actual, avances y desafíos en la protección y uso sostenible de la biodiversidad*. Proyecto PNUD/GEF CUB/92/G32, CUB/99/G81-Capacidad 21. Escandón Impresores, Sevilla, 183 pp.

The Sabana-Camagüey ecosystem is an archipelago in the northern central part of Cuba where tourism is the most important economic activity. The books (Alcolado et al., 1999, 2007) synthesise the results of more than thirteen years of research, based on an *ecosystem approach,* on the marine-coastal and terrestrial biodiversity of the archipelago. Biodiversity protection and conservation, and sustainable development, were addressed too. The second book (Alcolado et al., 2007) analysed the implementation of Coastal Integrated Management in the archipelago; one of the chapters was devoted to an economical environmental evaluation of the ecosystem goods and services.

Reference: Mugica, L., Denis, D., Acosta, M., Jiménez, A., and Rodríguez, A. 2006. *Aves acuáticas en los Humedales de Cuba.* Aquatic Birds on Cuban Wetlands. Editorial Científico Técnica. Habana, Cuba. 193 pp.

The first two chapters give an overview on Cuban main wetlands and the general features of aquatic birds. The next four chapters document the scientific results of more than 25 years of research on birds from Cuban Wetlands. The most important information that may be used to track future trends addresses the bird community associated to different Cuban wetlands. Relevant breeding information on Cuban waterbirds is also addressed, including main breeding sites, breeding periods for some colonial birds, colony size, and ecological aspects of breeding. The feeding ecology and food resources required by aquatic birds were studied, too. There is a chapter focused on birds in rice culture, an anthropic ecosystem that is heavily used by birds. These rice paddies may have a key role in buffering the loss and

damage of natural wetlands worldwide. Flooded rice fields provide foraging habitats for many breeding, and migrating species. The results presented here shows that in Cuba almost all common waterbirds are having a strong dependency of the paddies for their survival. The last chapter is focused on conservation and highlights the threats that are facing the aquatic birds and their environment and the Cuban efforts to preserve our biodiversity from the national level to the local level, including several study cases.

Reference: Acosta, M., and Mugica, L. 2006. Evaluación General de las Aves Acuáticas de Cuba. (http://www.birdlife.org/action/science/species/waterbirds/waterbirds_pdf/waterbirds_report_cuba_2006.pdf). 90 pp.

This is a 90-page monography that reviews the current knowledge on Cuban waterbirds, based on 181 published papers, 5 PhD thesis, 4 Master thesis, 22 Bachelor thesis and several project and technical reports that involve different aspects of the group (they are all listed in the document). The document has a detailed analysis of the representation of the aquatic birds in Cuba, their distribution and abundance throughout the country. It gives information on the current status and ongoing research projects related to Cuban threatened aquatic birds. Also, it addressed the key breeding sites all over the country. The last part is dedicated to the conservation programs and institutions focus on research and conservation in Cuba. The appendix includes the list of all aquatic birds, their frequency, a general assessment of their abundance, the main wetlands and up-to-date information of the published papers in each wetland.

Reference: Website of the Convention of Biological Diversity (http://www.biodiv.org). This website lists most of the recent reports that have been provided by the countries. Not all the countries have provided all the reports. The reports relevant to the present review are: National Biodiversity Strategies and Action Plans (NBSAP), Third National Report, Second National Report, First National Report, Alien and Invasive Species, Access to Genetic Resources and Benefit-Sharing, Forest Ecosystems, Mountain Ecosystems, Protected Areas, Technology Transfer and Cooperation, Implementation of Expanded Programme of Work on Forests (VFE).

The website of the Convention of Biological Diversity (http://www.biodiv.org) has a page for Cuba, which is a party of the Convention. The website includes the contact information of the corresponding national contact institutions, including persons. Currently, the Cuban reports

available online are the First, Second and Third National Reports (In Spanish); the National Biodiversity Strategy and Action Plan (In Spanish); and a Thematic Report on Protected Areas (In English). The National Biodiversity Strategy and Action Plan has been referred in the present Review (see Vilamajó et al., 2002).

Reference: Rodriguez Schettino, L. 2003. *Anfibios y reptiles de Cuba*. UPC Print, Vaasa, Finlandia. 169 pp.

This is a general book on Cuban amphibians and reptiles with very attractive pictures and general information on their ecology, behaviour and distribution. It has a checklist on amphibians (58 species) and reptiles (133 species) with information on endemism and distribution in 12 Cuban localities (www.ecosis.cu/ies/publicaciones.htm)

Reference: Diaz, L. M., and A. Cadiz (in press). Manual de los anfibios de Cuba. Abc Taxa, Belgium. (to be Published in 2008)

This handbook covers the 62 currently known species of Cuban amphibians, including tadpoles, eggs, and vocalisations. The book is complemented by a CD with the voices of 59 species. All species are depicted with colour photographs in 16 plates, line drawings, and half tone illustrations. Some identification keys are provided for adults and tadpoles. For each species the following information is provided: description, similar species, distribution, and ecological notes.

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Annex I . Short Biographical Sketches of the Working Group Members

Avelino G. Suárez Rodríguez

- Education: Licentiate in Physics, Havana University, Faculty of Physics. Training in plant eco-physiology (Institute of Botany, Czech. Academy of Science, Institute Botany, Cuban Academy of Science)

- Major positions: Senior researcher, Institute of Ecology and Systematic, Cuban Environmental Agency; Head Department Functional Ecology (189-2001); since 1993 Convenient Lead Author, Lead Author and Reviewer of the Second, Third and Forth IPCC Assessment, Regional Special Reports and editor of IPCC Report on *Climate Change and Biodiversity;* MEA member of the reviewer board; Secretary of the Cuban *Man and Biosphere*-UNESCO National Committee; Member of the Scientific-technical Assessment Council of the Cuban Environmental Agency and of the Scientific Council of the Institute of Ecology and Systematic. Coordinator of the *Biodiversity* sector of the First and Second Cuban National Communication to the UNFCCC. Expert on the CBD *Ad Hoc* Technical Committee on *Climate Change and Biodiversity* (2003-2004).

- Main areas of expertise and interest: Ecology; Plant eco-physiology; micro-climatology; mathematical modelling of biological processes; impacts, vulnerability and adaptation of climate change on biodiversity and regional (island states and Latin America) assessments.

René T. Capote-Fuentes, PhD

- Education: BSc in Biology, Havana University Faculty of Biology, Cuba, (2000); Degree in Environmental Management, Institute for Tropical Geography, Cuba (2001), Degree in Directing and Leadership, Higher Institute for Applied Science and Technology, Cuba (2005); PhD in Natural Sciences, Bonn University, Federal Republic of Germany (2007).

- Major positions: Researcher (coastal ecology and management), Institute of Ecology and Systematic (IES), Ministry of Science, Technology and Environment of Cuba (CITMA); Lecturer in Ecology, Havana University Faculty of Biology; Young Associate, Cuban Academy of Sciences (2006-2010); Member Cuban MAB-UNESCO Committee.

- Main areas of expertise and interest: mangrove ecology and management, coastal ecology and management, qualitative mathematical modelling, remote sensing, protected areas, climate change, institutional management.

Daysi Vilamajó Alberdi PhD

- Education: BSc in Biology, University of Havana, Cuba; PhD in Biological Sciences, University of Havana, Cuban Academy of Sciences Cuba.
- Major positions: Senior Researcher of Institute of Ecology and Systematic, Ministry of Science, Technology and Environment from 1991; Head Department, Ecology of Landscape, National Biodiversity Centre, Institute of Ecology and Systematic, Ministry of Science, Technology and Environment (1995 -2001); Project Coordinator GEF/PNUMA “National Strategy from Biodiversity and Action Plan” (1997-2001);Project Coordinator GEF/PNUMA 3010-01-09 **“**Assessment of Capacity-building needs for Biodiversity, Participation in CHM, and preparation of a second national report” (2002 -2007)
- Main areas of expertise and interest: Flora and Vegetation; application of remote sensing methods; diversity measures and their ecological meaning; integrated ecosystems management; ecosystems health, climate change especially community adaptation; environmental education and education for sustainable development; environmental communication.

Lourdes Mujica Valdés

- Education: Ph.D. in Biological Sciences, Universidad de la Habana, Cuba, 2000 Master of Science, Simon Fraser University, Vancouver, Canada, 1994. Bachelor of Science (Biology). Universidad de la Habana, 1981.

- Current Position: Auxiliary Professor, Faculty of Biology, University of Havana (since 1981, had been in different positions, all in the Faculty of Biology in the university) Ecology of aquatic birds in Cuban rice culture and natural wetlands. She is author of a book and a bird guide on the topic.

- Main area of expertise and interest: University Teaching, capacity building, environmental education, research and conservation on aquatic birds in wetlands, and farmlands (rice paddies).

José Gerhartz,

José L. Gerhartz graduated with a Bachelor Degree in Physical Geography as Honor Student of the Faculty and Most Outstanding Student in Research Work at the University of Havana in 1979. He was appointed as Assistant Professor of Physical Geography at the University of Camagüey. In early 1980s he teaches Physical Geography, Geomorphology and Cartography at the “Felix Varela” Pedagogical Institute, at Santa Clara, Villaclara. From 1983 to 1990 he worked as Senior Specialist on Natural Resources and Environmental Protection at the Physical Planning Department in the Province of Cienfuegos where he developed several studies related to marine and coastal planning and conservation and was appointed to managerial positions. From 1990 to 1997 he indistinctly worked as Senior Specialist on Natural Resources & Environment, Physical Planner and Information System Manager at the National Institute of Physical Planning in Havana. Here he was responsible for the development of a GIS to support national planning and carried out, among many others, GIS driven demographic analysis and an assessment of climate change impact on coastal human settlements in Cuba. He joined the National Centre for Protected Areas (CNAP) in late 1997 where he worked as GIS manager, Senior Conservation Planner and Researcher, during this stage of his career he worked on the design of the Cuban Protected Areas System, developed the late version of the Methodology for protected areas management plans, made several gap analysis at the national and ecoregional levels, and was the technical leader by the Cuban side in a MPA network design and gap analysis using Marxan under the technical leadership of WWF Canada.. In 2003 was appointed as Regional Information Officer for the Caribbean of the Small Island Development States

Network (SIDSNET) at the UWI Centre for Environment & Development at Mona Campus, Jamaica, where. During this period he was responsible for maintaining up to date the Caribbean Information at SIDSNet and providing advisory services as expert in biodiversity conservation in

small islands to several activities and meetings representing the Caribbean SIDS. He also kept his position at CNAP as Conservation Planner alternating his responsibilities in Jamaica and Cuba. In December 2005 after a successful completion of the contract at UWI he returned to his former position at CNAP full time. Since July 2006 he joined WWF as Cuba Field Manager.

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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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