Climate Change and Biodiversity in the European Union Overseas Entities

Jérôme Petit & Guillaume Prudent

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ONERC
Observatoire National sur les Effets du Réchauffement Climatique

This background paper, produced by IUCN in collaboration with ONERC, follows the proceedings of the IUCN conference *The European Union and its Overseas Entities: Strategies to Counter Climate Change and Biodiversity Loss,* which took place on Reunion Island from 7 to 11 July 2008.

The paper offers for the first time a comparative analysis of the 28 overseas entities of the European Union. It starts with a thematic analysis presenting the transversal threats on overseas entities in the face of climate change. Subsequent sections, specific for each of the 28 entities, provide some contextual data and an overview of their remarkable biodiversity, in addition to presenting the new threats resulting from climate change. Lastly, examples of responses to climate change or “best practices” are reported for selected territories.

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Katharine Mann

Acronyms List

AFSSA: Agence Française de Sécurité Sanitaire des Aliments
ARVAM: Agence pour la Recherche et la Valorisation Marine
BIOT: British Indian Ocean Territory
CCT: Chagos Conservation Trust
CIRAD: Centre de Coopération Internationale en Recherche Agronomique pour le Développement
CNRS: Centre National de Recherche Scientifique (France)
CRIOBE: Centre de Recherches Insulaires et Observatoire de l'Environnement
CRISP: Coral Reef Initiative in the South Pacific
CSIC: Consejo Superior de Investigaciones Científicas (Espagne)
DAF: Direction de l'Agriculture et de la Forêt
DCNA: Dutch Caribbean Nature Alliance
DEFRA: Department for Environment, Food and Rural Affairs (UK)
DIREN: Direction Régionale de l'Environnement (France)
DOM: Département d'Outre-Mer
DYNECAR: Dynamique des Ecosystèmes de Caraïbe
ECCM: Edinburgh Centre for Carbon Management
EDF: European Development Fund
ENA: Eastern North America
ESRI: Economic and Social Research Institute (Ireland)
EEZ: Economic Exclusive Zone
FAO: Food and Agriculture Organization of the United Nations
FCO: British Foreign and Commonwealth Office
GIEC: Groupe d'Experts Intergouvernemental sur l'Evolution du Climat
IAATO: International Association of Antarctica Tour Operators
IBA: Important Bird Area
IDDRI: Institut du Développement Durable et des Relations Internationales
IEA: International Energy Agency
IFRECOR: Initiative Française pour les Récifs Coralliens
IPCC: Intergovernmental Panel on Climate Change
IPEV: Institut Paul Émile Victor
IRD: Institut de Recherche pour le Développement
IUCN: International Union for the Conservation of Nature
JNCC: Joint Nature Conservation Committee
MNHN: Muséum National d'Histoire Naturelle
NACRI: Netherlands Antilles Coral Reef Initiative
OCTA: Overseas Countries and Territories Association
OMMM: Observatoire du Milieu Marin Martiniquais
ONCFS: Office National de la Chasse et de la Faune Sauvage (France)
ONERC: Observatoire National sur les Effets du Réchauffement Climatique
ONF: Office National des Forêts (France)
OCTs: Oversea Countries and Territories
ORs: Outermost Regions
PADD: Projet d'Aménagement et de Développement Durable
PCRDT: Programme Cadre pour la Recherche et le Développement Technologique
PECE: Profils Environnementaux de la Commission Européenne
PGEM: Plan de Gestion de l'Espace Maritime
RSPB: Royal Society for the Protection of Birds
SPC: Secretariat of the Pacific Community
STARP: Service Territorial des Affaires Rurales et de la Pêche
STINAPA: Stichting Nationale Parken (Fondation des parcs nationaux, Bonaire)
TAAF: Terres Australes et Antarctiques Françaises
ULPGC: Universidad de Las Palmas de Gran Canaria
UN: United Nations
UNEP: United Nations Environmental Program
UNESCO: United Nations Educational, Scientific and Cultural Organization
UNFCCC: United Nations Framework Convention on Climate Change
UNWTO: United Nations world tourism organization
USDA: United States Department of Agriculture
WMO: World Meteorological Organization
WRI: World Resources Institute
WWF: World Wide Fund

Foreword

Author: Russell A. Mittermeier

This report focuses on the great importance of a group of island and mainland territories scattered across the globe, but officially linked to Europe and largely overlooked by the global community. The 28 overseas regions and territories of the European Union (EU) host an outstanding diversity of landscapes, ecosystems and species and also play a key role in both climate mitigation and adaptation. Spread across all oceans and in South America, these regions and territories are home to far more biodiversity than the European continent itself.

New Caledonia alone (although smaller than Belgium) has a number of endemic species comparable to the entire European continent, and is largely responsible for the inclusion of France among the world's 18 "Megadiverse Countries", the only European country on the list. Greenland, which is an overseas territory of Denmark, has within its border the largest terrestrial protected area on Earth (Northeast Greenland National Park, 972 000 square kilometers). And French Guiana, a French department in northern South America and a full part of the EU, has one of the least disturbed areas of rain forest on Earth, a critically important piece of the Guiana Shield Region of Amazonia. Indeed, almost all European territories are located either in Biodiversity Hotspots[1] or High Biodiversity Wilderness Areas [2]. Additionally, EU overseas entities together have the world largest and most diverse marine Exclusive Economic Zone (EEZ), and the UK has recently designated around the Chagos Islands the largest marine protected area on Earth (544 000 square kilometers, an area twice the size of the UK's land surface).

Until very recently, these regions have received very little attention from both the European Union and the global environmental community. Moreover, it has been extremely difficult for those few conservation organisations interested in supporting projects and programmes in these territories to find funding from traditional sources like bilateral aid agencies and multilateral development banks because they are officially part of wealthy European nations. However, awareness is now growing that the seven Outermost Regions (ORs) and twenty-one Overseas Countries and Territories (OCTs) of the EU are of great global ecological importance, that they face serious challenges, and that they should receive specific attention and funding.

People need nature to thrive. All over the world, the economic and social importance of biodiversity and the ecosystem services derived from it are becoming increasingly clear, along with the fact that these natural systems are fundamental to human well-being, poverty alleviation, and any and all efforts to achieve truly sustainable development. The Economics of Ecosystems and Biodiversity (TEEB) study, supported by the United Nations Environment Programme (UNEP) and the European Commission (EC), UK Department for Environment Food and Rural Affairs (DEFRA), the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Norwegian Ministry of Foreign Affairs, has clearly demonstrated that current rates of ecosystem degradation could reduce global GDP by 6 to 8 % by 2050. It also concluded that coral reefs worldwide provide ecosystem services worth 170 billion dollars a year, and that having 30% of the world's oceans managed as marine protected areas would bring an annual economic benefit of 4 to 5 trillion dollars, for a cost of 40 to 50 billion dollars.

Most EU overseas entities are also located in regions where many communities depend directly on biodiversity for their daily needs, heightening the need for increased attention to these entities. Just to cite a few examples, in the Caribbean (which has 12 European overseas entities), climate change and the degradation of coral reefs is putting at risk both fisheries and the tourism industry. In French Polynesia, large scale degradation of coral reefs could cause even greater challenges, impacting world-renowned landscapes, putting at risk the pearl industry and increasing the islands' vulnerability to sea level rise. As this publication clearly shows, each of Europe's 28 overseas entities, in one way or another, needs to place the highest possible priority on the protection and restoration of natural ecosystems.

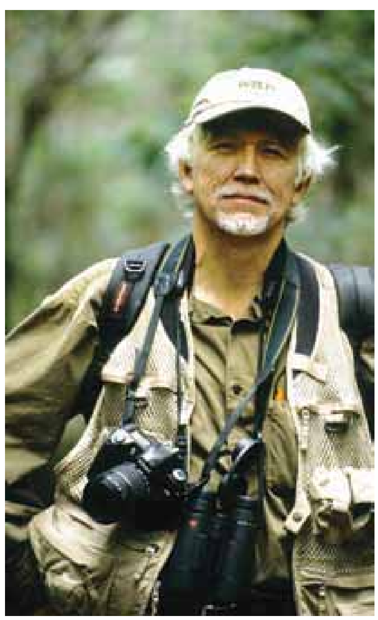
This report is the first ever to comprehensively address the ecological challenges at the scale of all 28 EU overseas entities. As a follow-up to the very successful 2008 Reunion Island Conference, entitled «The EU and its Overseas Entities: Strategies in the Face of Climate Change and Biodiversity Loss», this publication represents a major effort to raise awareness and inspire action at local, regional, national, European and global levels. I was pleased and honored to be able to participate in this Conference, representing IUCN, and was most impressed with its content, quality, and long-term

[1] Hotspots designate 34 areas that cover only 2.3 percent of the Earth's land surface but hold especially high numbers of endemic species and have already lost at least 70 percent of their original natural vegetation.
[2] High Biodiversity Wilderness Areas designate areas that hold outstanding biodiversity and where the original vegetation - at least 70 percent - has remained intact.

vision, and the fact that it highlighted geographical entities that I had been concerned about for a long time, but in which it was sometimes frustrating to work because of a lack of global attention and dedicated funding for biodiversity.

Achieved under the leadership of IUCN and with the support of France, these efforts hopefully signal a new era in which EU overseas entities will receive more technical assistance and dedicated funds from the European Union itself and other donors and stakeholders, with the ultimate goal of protecting their unique biodiversity and increasing the resilience of their ecosystems and societies to climate change.

It is now appropriate, and indeed imperative, that the EU shows major leadership and develops new initiatives, using the experience acquired through its Natura 2000 network and generally mobilising its research and technical capacities. In its overseas entities, the EU has a unique opportunity to play a strong global role in addressing one of the most important priorities on the 21st century agenda, the management of interactions between biodiversity, ecosystem services, climate change, and human communities. We hope that this publication will help stimulate such action and open a new era of opportunity for these critically important and almost forgotten parts of our planet.



Russell A. Mittermeier
President, Conservation International
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Councillor for North America and the
Caribbean, IUCN

Preface

Author: Dr Chris D Thomas

The Cagou *(Rhynochetos jubatus)* is an endemic bird from New Caledonia

Imaxandco

The Kagu brings a smile to anyone who is fortunate enough to see or hear one, the only surviving representative of an entire family of birds. It could be mistaken for an over-energetic, almost demented, flightless heron with silver-grey plumage, a wonderful crest, coral-orange legs and bill, and a cacophony of laughing-yelping calls. Its eccentric quick-step walk, freeze-still then peck or probe routine is a picture of concentration as it hunts for worms and snails on the forest floor of New Caledonia – forests that not only provide a home for this and many other extraordinary species but also help maintain soil stability and water for human consumption and hydroelectric power. This spectacular island is also fringed by magnificent coral reefs, one of the most important regions in the world for marine biodiversity and a critical source of food and tourist income for the human population.

Unfortunately, climate change is already exerting pressures on wildlife in all of the European Union overseas territories. Climate change respects no boundaries, and bleaching damage to the heat-sensitive coral reefs of the EU territories has already been widely observed, including in New Caledonia. Greenhouse gas emissions are generated disproportionately by industrialised countries, but the consequences are felt all over the world. These impacts are felt in places that have high levels of biodiversity and that do not necessarily have sufficient resources to deal with the consequences. As such, it behoves continental EU nations to reduce emissions, and also to help their overseas territories to adapt to changes that are already inevitable.

This report is, therefore, a very welcome move to recognise the consequences of climate change for the EU overseas territories, and specifically for their biodiversity. The human communities of the territories rely heavily on this biodiversity for a wide variety of ecosystem goods and services that range from food and fisheries, to water resources and fertile soils, through to tourism and coastal protection. Without the biodiversity of their natural ecosystems, the human populations of the territories would be greatly impoverished.

Many of the potential ills that face the world from climate change are encapsulated within the EU overseas territories. The EU territories range from the Antarctic to the Arctic, and from atolls that reach only a few metres above sea level to lofty mountain peaks. Gradual melting of the Greenland ice sheet, combined with thermal expansion of the oceans and increases in storm intensity, will contribute to an increasing likelihood of coastal inundation, threatening coastal human populations and wildlife. Terrestrial species that are confined to low-lying islands, such as the critically endangered Polynesian Ground Dove, have no-where else to go. Functioning natural coastal ecosystems, especially reefs, salt marshes and mangrove forests, have the potential to minimise these impacts, and should therefore be carefully protected.

Climate change has joined over-exploitation by humans, invasive species, habitat destruction and pollution (other than greenhouse gasses) as the fifth major global threat to biodiversity. These pressures are not acting alone. A combination of over-fishing and coral bleaching may prove fatal for the reefs that play such an important role in the life and economies of many of the territories. Habitat destruction, warming and altered rainfall patterns may combine to generate seasonal droughts in some regions, whereas substantially increased rainfall and storms could bring serious erosion to devegetated tropical islands, threatening human populations and wildlife alike. Increased elevations of invasive birds, mosquitoes and bird malaria may join forces to restrict native island species to ever-higher elevations, and eventually to eliminate them completely. In continental Europe and elsewhere, many species will survive climate change by moving their distributions to higher latitudes, but this is not an option for many of the species that are confined to the EU overseas territories. Species that are restricted to oceanic islands, in particular, must survive where they are, or perish.

More species may be at risk of global extinction from climate change in the territories than in the entire continent of Europe, but no formal analyses exist. As country after country within continental Europe prepares biodiversity adaptation strategies for climate change, little attention has been given to the rest of the world, where most of the impacts of EU emissions are being felt. If adaptation is at least partially about putting right some of the wrongs that continental EU emissions have caused, then the majority of the effort and resources the EU devotes to climate change adaptation should be directed abroad, including to our overseas territories. This is important for biodiversity, and equally so for the human communities that rely heavily on ecosystems services for their quality of life – and in some cases survival.

Recognising the problem is vital. But this is only a beginning. Europe has many of the finest climate scientists, it leads the world in documenting the responses of biodiversity to climate change, and it is a leader in projecting the future potential consequences of climate change for wildlife. Let this report be a call to EU scientists and policy makers to pay greater attention to the impacts of climate change in our overseas territories, and to European governments, funding agencies and NGOs to facilitate this work so as to contribute to the development of adaptation strategies by the administrative authorities of the EU overseas territories. With such an increase in attention and effort, it is possible that many of our overseas territories could become inspiring exemplars of conservation and sustainability, rather than casualties of our insatiable greed for hydrocarbons.

Dr Chris D Thomas
Professor of Conservation Biology
University of York

Introduction

Author: Jérôme Petit (IUCN)

Climate change is a major threat to global biodiversity. From the tropics to the Poles, the world's ecosystems are all under pressure. A study published in the scientific journal *Nature* posited that 15 to 37% of terrestrial animal and plant species could be at risk of extinction because of human-induced impacts on climate (Thomas et al., 2004).

Scattered across the four corners of the Earth, European Union overseas entities, are home to a biological diversity that is as rich as it is vulnerable. Located in several global biodiversity hotspots, these territories are home to a far greater number of endemic animal and plant species than continental Europe. However, this natural wealth is under pressure from numerous quarters: habitat destruction, invasive alien species, pollution, over-exploitation of species; no territory has been spared. Today, climate change represents an additional threat to these ecosystems, and one which could possibly end up being as damaging as all the others combined.

As a result of the remarkable diversity of their environments, European overseas entities provide a real cross section of the impacts of climate change on global biodiversity. They serve to highlight the extent of these impacts on the majority of global ecosystems and on a large variety of taxonomic groups. Furthermore, given that overseas ecosystems are particularly vulnerable to climate change, they can serve as beacons for the European Union. With their wide geographic spread, they act as an early warning system for the effects of climate change on ecosystems generally.

"Islands are the bellwethers of international environmental policy. The world will see their success or failure on our islands first".
James Alix Michel, President of the Seychelles (IUCN Global Islands Survey).

In addition to raising the alarm, the overseas entities of Europe can also set an example. Overseas entities are among the first regions to have been affected by climate change; they could also be among the first to adapt to its effects and to implement strategies to respond to them. Overseas entities can act as learning laboratories for the creation of policies, strategies or technologies that can be used to adapt to or mitigate the effects of climate change. Such innovations, conceived on the European islands, can then be rolled out and adapted to surrounding developing countries. With European Union assistance, overseas entities could become

Carole Manry

Nukutapu islet in Wallis et Futuna

centres of excellence for sustainable development research, ecosystem management, biodiversity protection, renewable energy development and climate change adaptation.

The International Union for the Conservation of Nature (IUCN), in collaboration with the *Ministère de l'Intérieur, de l'Outre-mer et des Collectivités territoriales* (Ministry of the Interior, the Overseas Territories and Entities), the *Conseil Régional de La Réunion* (Regional Council of the Reunion Island) and the *Observatoire National français des Effets du Réchauffement Climatique* (ONERC) (French National Observatory for the Effects of Climate Change), decided to shine the spotlight on the European overseas entities and organize an international conference on the theme of climate change and biodiversity loss in these regions. The conference, which has taken place from 7 to 11 July 2008 on the Reunion Island, was officially endorsed by the French Presidency of the European Union. For the first time, this gathering brought together the 27 Member States and their 28 overseas entities, to stimulate a common debate. The objectives of this event were (1) to strengthen awareness among European institutions, the 27 Member States of the European Union, regional and global institutions, civil society and the media, of the unique natural heritage of overseas Europe, the threats it faces and the opportunities it has to offer; (2) to strengthen the effectiveness of action and cooperation among the EU, the Member States and the European overseas entities, in efforts to adapt to climate change, adopt exemplary energy policies and protect and sustainably manage their biodiversity; and (3) to strengthen regional cooperation between the European Union overseas entities and their neighbours, as well as build capacity among these entities to ensure a stronger voice in international environmental debates.

Prior to this conference it was necessary to take stock of the available scientific knowledge and to lay the groundwork for discussions. IUCN, in collaboration with the ONERC and other partners, decided to undertake a review of the risks inherent to climate change; this report is based on that study. In order to carry out this large-scale study, IUCN called on a network of more than 80 experts, researchers, academics, members of associations, public administrations, and the private sector based in the territories concerned. This consultative process enabled information to be gathered from a wide range of field actors. This information was then entered into a database and supplemented with a bibliography of scientific publications, summary documents and technical notes. The data have been summarised and transcribed in the current document. Upon completion, the document was sent for review to all contributing experts.

The objective of this paper, which is intended as a reference document, is to establish the current state of existing knowledge on the impacts of climate change on the biodiversity of the European Union overseas entities. This document starts with a thematic analysis of European overseas biodiversity, the reality of climate change, the new threats it presents for natural resources, and the resulting socio-economic implications. This analysis presents a general overview of the global and sectoral data related to overseas territories, and highlights certain notable examples in the individual regions. The document then provides a geographical analysis of the impacts of climate change on biodiversity in the 28 European Union overseas entities. These have been divided into seven large geographical areas: the Caribbean, the Indian Ocean, the South Pacific, Macaronesia, the Amazon, the Polar Regions and the South Atlantic. For each entity a non-exhaustive overview of the current state of biodiversity, observed or potential impacts of climate change on the natural resources, and the resulting socio-economic implications are presented. For some regions, examples of strategies to adapt to or mitigate the effects of climate change that deserve particular mention have been highlighted.

The Message from Réunion Island, adopted by conference participants, is presented in the appendix of this document. It contains 21 proposals aimed at the ORs, the OCTs, and their regions of the world. It is strengthened by a portfolio of recommended actions and measures resulting from 11 roundtables and workshops, in which more than 400 people participated.

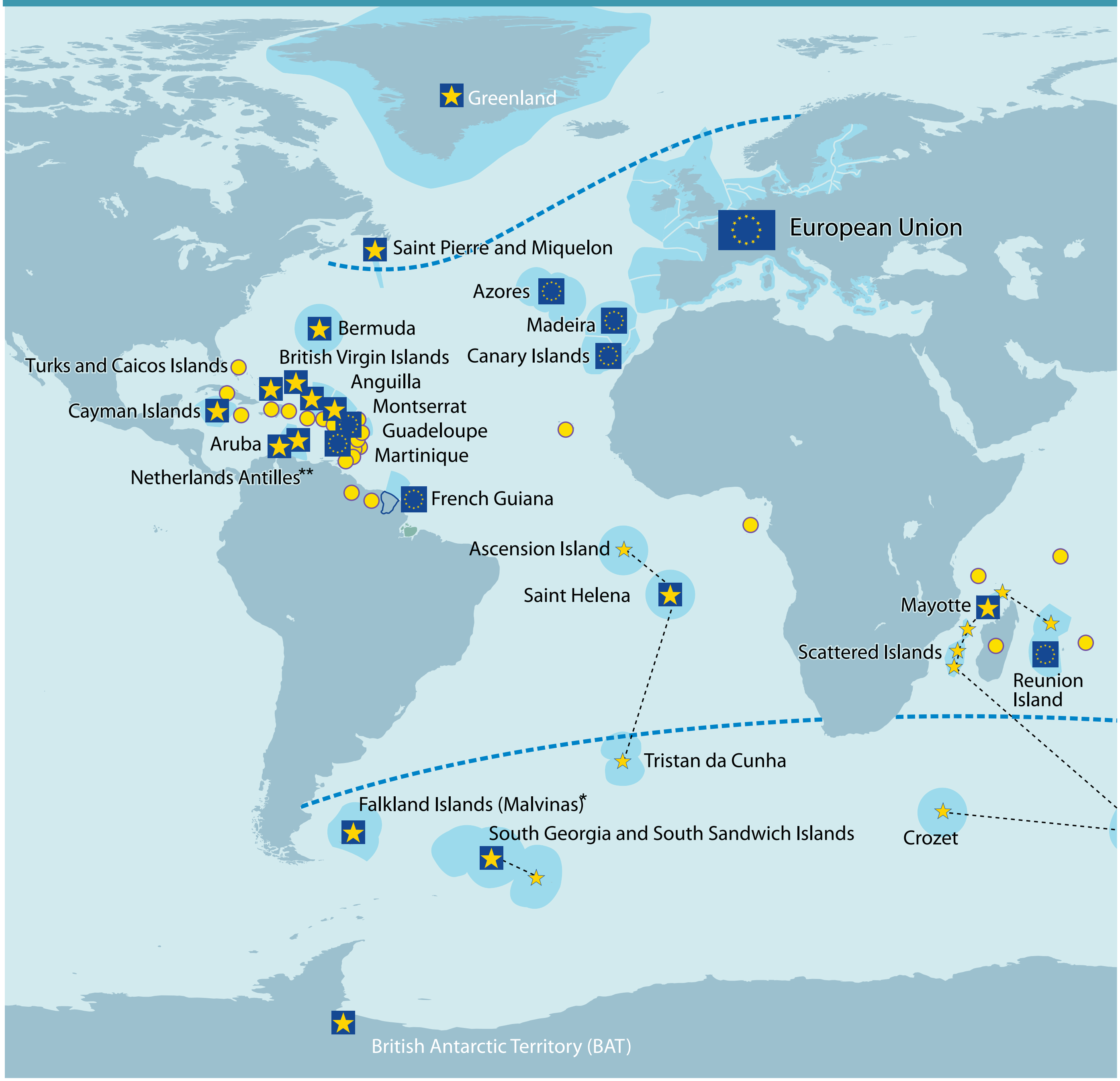
1. Thematic Analysis

Author: Jérôme Petit (IUCN)

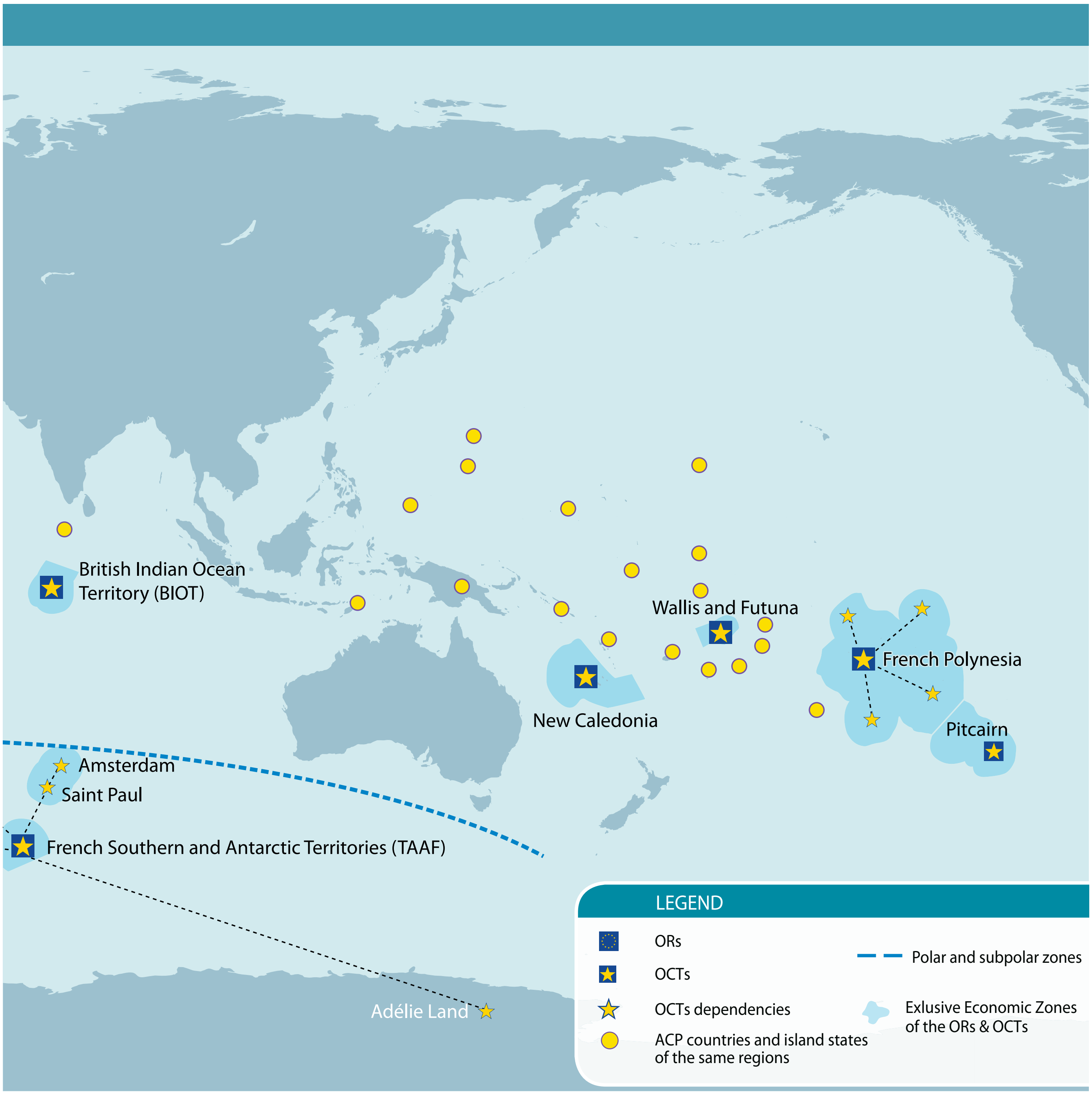
European Union Overseas Entities

1.1

Map 1: European Union Overseas Entities in the World



* A dispute exists between the Governments of Argentina and the United Kingdom of Great Britain and Northern Ireland concerning sovereignty over the Falkland Islands (Malvinas).
** Since October 2010 the Netherlands Antilles are disbanded, changing the constitutional status of federation's five islands - Curacao and St Maarten have become autonomous states within the Netherlands; Bonaire, St Eustatius and Saba are now autonomous special municipalities of the Netherlands.


British Indian Ocean Territory (BIOT)
Wallis and Futuna
French Polynesia
New Caledonia
Pitcairn
Amsterdam
Saint Paul
French Southern and Antarctic Territories (TAAF)
Adélie Land
LEGEND
ORs
OCTs
OCTs dependencies
ACP countries and island states of the same regions
Polar and subpolar zones
Exlusive Economic Zones of the ORs & OCTs

The European Union includes a multitude of satellite territories, for the most part islands scattered throughout the planet, largely outside the European continent. Six European Union Member States: the United Kingdom, France, the Netherlands, Portugal, Spain and Denmark, have a total of 28 overseas entities, distributed throughout three oceans (Atlantic, Indian, Pacific) and two continents (South America and Antarctica).

Overseas Europe, which extends over an area of 4.4 million km^2, has a terrestrial surface area roughly equivalent to that of the continental European Union. Greenland (2.16 million km^2), the British Antarctic Territories (1.7 million km^2), Adélie Land (432,000 km^2) and French Guiana (86,504 km^2) make up the largest portion of this area. The rest of the territory consists of islands that have a combined surface area of only 58,000 km^2, or 1,3% of the continental European Union.

With a population of about 5.6 million (1.9 million of whom are in the Canary Islands), overseas Europe is home to 1.15% of the European population. While the Polar Regions are practically uninhabited, the population density of the tropical islands tends to be very high, with 578 inhabitants per km^2 in Mayotte for example, as against 110 inhabitants per km^2 in continental France, or even 1,241 inhabitatns per km^2 in Bermuda as against 252 inhabitants per km^2 in the UK.

Overseas entities have different status and are bound by different jurisdictions which vary according to the individual arrangements they have with the Member States on which they depend. Regions, departments, territories, countries or communities; some are in the process of becoming independent or autonomous and each enjoys a different level of sovereignty. However, the European Union only recognises two official legal appellations to classify its entities: outermost regions (OR) and overseas countries and territories (OCT).

Outermost regions (OR)

Outermost regions are an integral part of the European Union. They are bound by the directives of the European Commission in the same way as all other Members State regions. The European Union has seven ORs, which are dependencies of three Member States. Guadeloupe and Martinique in the Caribbean, French Guiana in South America and the Reunion Island in the Indian Ocean are ORs, but they are also French overseas departments (OD). The Azores and Madeira in Macaronesia, in the North-East Atlantic, are ORs and autonomous regions of Portugal. Finally, the Canary Islands, in Macaronesia, are both ORs and part of the autonomous community of Spain (see Map 1).

Overseas countries and territories (OCT)

Created under the Treaty of Rome in 1957, the status of overseas countries and territories has its own specific legal and political structure. Those entities with OCT status are not part of the European Union and are not included in the Schengen Space, despite being dependencies of Schengen member countries. They nonetheless benefit from association with the European Union – covered in Part IV of the Treaty of the European Union – and qualify for European Development Fund (EDF) grants. Their inhabitants are usually citizens of the State with which the territory is associated.

The European Union numbers 21 OCTs belonging to five Member States. Most of these entities are islands situated in the tropics. The Netherlands Antilles, Aruba (Netherlands), the Cayman Islands, the British Virgin Islands, Turks and Caicos Islands, Bermuda, Anguilla and Montserrat (United Kingdom) are in the Caribbean. Mayotte (France) and the Chagos Archipelago (United Kingdom) are in the Indian Ocean. The islands in the South Pacific include French Polynesia, New Caledonia, Wallis and Futuna (France), and Pitcairn (United Kingdom). Saint-Helena and dependencies (United Kingdom), are in the South Atlantic.

There are also several overseas entities of the European Union in the Polar and sub-Polar Regions: Greenland (Denmark) and Saint Pierre and Miquelon (France) close to the North Pole; the Falkland Islands (Malvinas) (United Kingdom), the French Southern and Antarctic Territories (TAFF – France), South Georgia and the South Sandwich Islands (United Kingdom), and the British Antarctic Territories (United Kingdom) close to the South Pole (see Map 1).

Jean-Philippe Palasi

European flag in New Caledonia

Table 1: European Overseas entities contextual data and related Member States (CIA Word Factbook 2008, MDGI 2008)

Geographical area	Inhabitants	Area (km²)	Population density (inh./km²)	No. main islands	Max. elev.	EEZ (km²)	GDP /inhab. (€)	Unemployment rate (%)	CO_2 emissions to/inh./yr.
United Kingdom (cont.)	**60.943.912**	**241.590**	**252,3**		**1.343**	**764.071**	**24.300**	**5,4**	**8,9**
United Kingdom (o.s.)	**193.407**	**1.727.113**	**0,1**	**165**	**2.934**	**3.201.172**			
Anguila	14.108	102	138,3	1	65		5.500	8,0	
Bermuda	65.773	53	1.241,0	4	76		44.000		7,6
BIOT	4.000	60	66,7	55	15	637.000			
South Georgia	20	3.903	0,0	19	2.934				
Cayman Islands	47.862	262	182,7	3	43		19.700	4,4	6,0
Falkland Islands (Malvinas)	3.140	12.173	0,3	2	705		15.700	0,0	13,4
British Virgin Isl.	24.004	153	156,9	60	521	80.701	24.200	3,6	2,8
Montserrat	9.638	102	94,0	1	930	8.250	2.100	6,0	12,2
Pitcairn	47	62	0,8	1	347	837.221			
St Helena & terr.	7.601	413	18,4	3	2.062	1.638.000	3.500	14,0	1,6
Brit. Ant. Terr.	0	1.709.400	0,0	8					
Turks and Caicos	22.352	430	52,0	8	49		7.200	11,0	
France (cont.)	**60.876.136**	**551.695**	**110,3**		**4.807**	**349.000**	**21.700**	**8,3**	**9,5**
France (o.s.)	**2.580.514**	**546.941**	**4,7**	**160**	**3.070**	**10.505.300**			
Guadeloupe	420.000	1.628	258,0	13		90.000	5.700	22,7	4,1
French Guiana	230.000	86.504	2,7	0		130.000	11.900	24,5	4,3
Scattered Islands	20	44	0,5	6		640.000			
Martinique	397.820	1.128	352,7	1		45.000	14.300	25,2	5,6
Mayotte	216.306	374	578,4	2	660	73.600	2.200	25,4	
New Caledonia	224.824	18.575	12,1	5	1.628	1.400.000	12.000	7,1	8,1
French Polynesia	283.019	3.660	77,3	118	2.241	5.030.000	11.000	13,0	2,5
Reunion Island	785.000	2.512	312,5	1	3.070	318.300	12.000	30,0	3,1
St Pierre and Miqu.	6.125	242	27,0	3	240	12.400	4.400		
TAAF	33	432.000	0,0	8	1.090	2.500.000			
Wallis and Futuna	16.448	142	115,0	3	765	266.000	2.000	15,2	
Netherlands (cont.)	**16.645.313**	**33.883**	**491,3**		**322**		**23.900**	**3,2**	**9,8**
Netherlands (o.s.)	**326.910**	**1.153**	**283,5**	**6**	**862**				
Netherlands Antil.	225.369	960	234,8	5	862		8.400	17,0	44,1
Aruba	101.541	193	526,1	1	188	1	4.900	6,9	19,0
Portugal (cont.)	**10.676.910**	**91.951**	**116,1**			**327.667**	**10.700**	**7,7**	**5,8**
Portugal (o.m.)	**485.861**	**3.161**	**153,7**	**12**	**2.351**	**1.400.000**			
Azores	241.763	2.333	103,6	9	2.351	954.000			
Madeira	244.098	828	294,8	3		446.000			
Spain	**40.491.051**	**499.542**	**81,1**				**14.500**	**8,3**	**7,5**
Canary Islands	2.025.951	7.447	272,0	7	3.718				
Denmark	**5.475.791**	**43.094**	**127,1**		**173**		**29.700**	**2,8**	**8,7**
Greenland	56.326	2.166.086	0,0	1	3.700		12.600	9,3	9,9
European Union	**494.296.878**	**4.376.780**	**112,9**		**4.807**	**25.000.000**	**13.300**		**7,5**
Total Overseas	**5.668.969**	**4.451.901**	**1**	**351**	**3.718**	**15.106.472**			

cont. = continental; o.s.= overseas ; No. main isld.=Number of main islands; Max. elev. = Maximum elevation; EZZ = Economic Exclusive Zone; GNP/inhab. = Gross National Product per inhabitant; CO_2 emissions to/inh./yr.= Emissions of CO_2 in tonne per inhabitant per year

Biodiversity in the Overseas Territories

1.2

1.2.1 An exceptional biological diversity

Biodiversity is defined by the Convention on Biological Diversity (CBD) 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 European Union overseas entities are home to an exceptional biodiversity. Situated in the three large oceans and at a range of latitudes, these entities play host to more endemic species (species that are exclusive to a restricted geographical area) than are found on the whole of continental Europe.

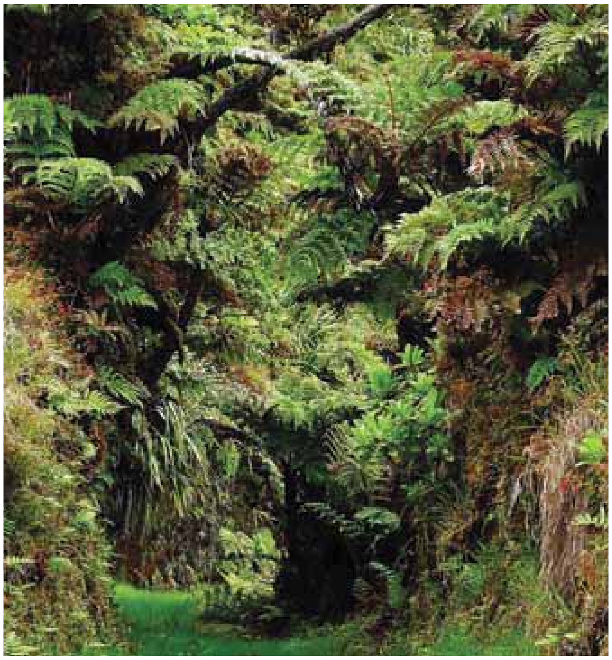
As a general rule, islands are major repositories of endemism. Their ecosystems have developed in isolation, far away from the continents, which has led to the development of new species, adapted to the unique constraints of island living. Each island has a distinct climate and geography, which results in fauna and flora that are tailored to these unique characteristics. The islands are therefore a fabulous laboratory of species' evolution; overseas Europe, with more than 350 tropical, temperate and polar islands, is home to an immeasurable wealth of habitats and species.

For example, Ascension Island supports the second largest Green turtle rookery in the Atlantic; Gough Island (Tristan da Cunha) is, arguably, the most important seabird island in the world; and the reefs of the Chagos Archipelago (British Indian Ocean Territory) feature among some of the most pristine and best protected in the Indian Ocean (and account for some 1.3% of the world total) (Procter et al., 1999). New Caledonia alone has 2,423 endemic species; France only has 353. In Canary islands, that represent 1.5% of the surface of Spain, are living 50% of all the endemic plant species (Martin Esquivel, personal communication). Thanks to French Guiana, the European Union is also present in the Amazon. This region, which only accounts for 7% of global land area, is home to more than half of the animal and plant species in the world. French Guiana's 83,000 km² of Amazon forest contains about half of France's biodiversity (29% of plants, 55% of vertebrates and 92% of insects) in an eight of its area (Gargominy, 2003).

Andrew C Hilton

European overseas tropical islands contain an extremely rich biodiversity (Opunohu Bay in Moorea)

The waters of the European overseas tropical islands are home to an exceptional collection of marine fauna and flora. French Polynesia alone has 20% of the world's atolls. With 14,280 km2 of reefs, New Caledonia is home to the world's second largest coral barrier reef. Finally, the Canary Islands boast 29 of the 81 species of whales, some 36% of the world's whale population.



Andrew Darlow

Natural forest in Saint Helena Island

1.2.2 Indispensable ecosystems for populations

Ecosystems provide goods and services that are crucial to the well-being of populations. This is particularly true of the overseas entities, whose inhabitants are often rural and depend upon natural resources for their subsistence. Ecosystems provide four types of services to populations: provisioning services, regulating services, cultural services and support services (MEA, 2005).

Provisioning services are those provided directly by the ecosystems to populations, such as food, fresh water, medicinal plants, wood, etc. Subsistence agriculture, livestock and fishing still play an extremely important role in the lives of the rural populations of New Caledonia, French Polynesia and Mayotte, for example. The economy of Martinique is primarily based on sugar cane, banana and pineapple plantations. In contrast, the ecosystems of

patochh

Rural populations on tropical islands rely heavily on natural resources (fruit market in Guadeloupe)

the French Guiana Amazon forest have an extraordinary potential as a source of chemical compounds and biological resources for use in the elaboration of new medicines, cosmetics, food additives or biomaterials.

The regulating services provided by ecosystems include the maintenance of natural equilibriums, including climate regulation, coastal protection, erosion limitation, pest control, water quality regulation, pollination, etc. In very rugged volcanic islands such as those of Macaronesia or the Reunion Island for example, healthy forests play an important part in stabilizing the soils and preventing land slides. The intact mangroves of New Caledonia help to eliminate and hasten the decomposition of organic debris deposited in the lagoon, provide food and shelter for many fish species, and protect the coasts from erosion.

The cultural services are the recreational and cultural benefits which ecosystems deliver through spiritual enrichment, leisure activities and pleasing aesthetics. Ecosystem diversity finds expression in the diversity of regional cultures and identities, through art, spiritual and religious values, or the beauty of the landscapes. In French Polynesia, for example, traditional paintings and tattoos often make reference to natural resources. Similarly, the attractiveness of the tropical islands as tourist destinations is highly dependent on the beauty of the well-preserved natural landscapes such as coral reefs or beaches. Biodiversity, in addition to being indispensable to the ecological equilibrium of natural environments, also has social, economic and cultural value.

Finally, the support services are necessary for the production of all other ecosystem services. They include soil formation, photosynthesis, primary production, nutrient cycling and water cycling.

btan87

Tourism is linked to the beach and lagoon quality (Seven Mile beach in Bonaire)

1.2.3 A threatened natural heritage

Island ecosystems are fragile and particularly vulnerable to human-induced impacts. Approximately 75% of extinctions of animal species and 90% of bird species extinctions that have taken place in the last 400 years have occurred on islands (Buckley, 2007). In addition, 23% of island species are currently "critically endangered" or "endangered", in comparison to 11% for the rest of the planet (INSULA, 2004). Having developed in an isolated and relatively protected manner, island ecosystems are particularly vulnerable to changes in the environment, and especially to exotic species introduced by humans, and against which they have no resistance.

The IUCN Red List indicates that 523 species found in French overseas entities are gobally threatened (that is to say, critically endangered CR, endangered EN, or vulnerable VU) as against 124 species in mainland France. Some 187 species found in British overseas entities are threatened, compared to 51 in the United Kingdom. Similarly, 31 species found in Dutch overseas entities are threatened, compared to 26 in the Netherlands. Finally, throughout the European overseas entities (excluding the Canary Islands, Madeira and the Azores), 667 species are threatened compared to 701 in continental Europe (see Table 2). At the same time, an analysis of the main taxonomic groups has revealed that 32 species of birds are threatened in French Polynesia, compared to five in mainland France; 16 species of fish in Aruba, compared to nine in the Netherlands; 25 species of invertebrates in the Bermuda Islands, compared to eight in the United Kingdom; and finally, no less than 219 species of plant are threatened in New Caledonia, compared to only seven in mainland France (IUCN Red List 2008). Taken together, these figures are evidence of the extreme vulnerability of biodiversity in European overseas entities. The ecosystems in these regions are particularly fragile and their resilience in the face of a new threat like climate change will be far more limited than that of continental Europe.

Island biodiversity in the European Union overseas territories faces numerous threats. The Millennium Ecosystem Assessment has identified five main drivers of change in global biodiversity: direct destruction of habitats, invasive species, over-exploitation of resources, pollution and climate change. These threats are present in all the overseas entities of the European Union. Most of the overseas territories are situated in the global "biodiversity hotspots"; these are regions of the world where the biodiversity is both very rich and very threatened.

Table 2: Threatened species in the European overseas entities and in the related Member States (IUCN Red List 2008). CR (Critically endangered), EN (Endangered) and VU (Vulnerable) categories.

	Mammal	Birds	Reptiles	Amphib.	Fishes	Mollusc.	Oth. invt.	Plants	Total
France (cont.)	**15**	**5**	**5**	**2**	**27**	**34**	**29**	**7**	**124**
France (o.s.)									**523**
New Caledonia	6	15	2	0	16	11	1	219	270
French Polynesia	3	32	1	0	12	29	0	47	124
French Guiana	9	0	7	3	22	0	0	16	57
Reunion Island	4	6	3	0	6	14	2	16	51
Guadeloupe	6	2	5	3	15	1	0	8	40
Martinique	1	3	5	2	15	1	0	9	36
TAAF	2	13	0	0	2	0	0	0	17
Wallis and Futuna	0	9	0	0	3	0	0	1	13
Mayotte	1	4	2	0	1	0	1	0	9
St Pierre and M.	0	1	0	0	1	0	0	0	2
UK (cont.)	**9**	**3**	**0**	**0**	**16**	**2**	**8**	**13**	**51**
UK (o.s.)									**187**
Bermuda	2	1	2	0	13	0	25	4	47
St Helena and terr.	1	18	1	0	11	0	2	26	59
Br. Virgin Islands	0	1	6	2	14	0	0	10	33
Pitcairn	0	11	0	0	7	5	0	7	30
Montserrat	2	2	3	1	15	0	0	4	27
Falkland Islands (Malvinas)	4	10	0	0	5	0	0	5	24
Cayman Islands	0	1	5	0	14	1	0	2	23
Turks and Caicos	1	2	5	0	13	0	0	2	23
Anguilla	1	0	4	0	15	0	0	3	23
Chagos	0	0	2	0	7	0	0	1	10
South Georgia	1	7	0	0	0	0	0	0	8
Netherlands (cont.)	**10**	**1**	**0**	**0**	**9**	**1**	**5**	**0**	**26**
Netherlands (o.s.)									**31**
Neth. Antilles	2	1	6	0	16	0	0	2	27
Aruba	2	1	3	0	16	0	1	0	23
Denmark	**3**	**3**	**0**	**0**	**11**	**1**	**10**	**3**	**31**
Greenland	8	0	0	0	6	0	0	1	15
Spain	**20**	**15**	**17**	**5**	**51**	**27**	**35**	**49**	**219**
Portugal	**15**	**8**	**2**	**0**	**39**	**67**	**16**	**16**	**163**
Total overseas entities									**667**
Europe (cont.)									**701**

cont. = continental; o.s. = overseas ; Mamm. = Mammals; Amphib. = Amphibians; Oth. Invert. = Other Invertebrates

Habitat destruction and fragmentation

The destruction of the natural ecosystems of the overseas entities began with the first human settlers who cleared land to make way for crops and human installations. For example, the natural forests of Mayotte were almost entirely converted to sugar cane plantations in the 19th century; this crop has had a major impact on ecosystems throughout the Caribbean. More recently, direct destruction of habitats has gained pace because of rapid population growth throughout the overseas entities, and the increasing pace of development of the tourist industry. At a rate of 1.8% per year, population growth on the Reunion Island is the fastest of all the regions of the European Union. The population of Mayotte has increased 3.5-fold in less than 40 years. Furthermore, the tourist industry has recently become the most important economic activity in most of the European overseas tropical islands. The Canary Islands host some 10 million visitors a year.

Rapid population growth in Mayotte threatens biodiversity

In the French Antilles, the number of visitors increased by 9% in 2006, and the income generated by tourism in French Polynesia accounts for some 70% of the territory's resources (ACCDOM 2008). Tourism has a major impact on biodiversity, through the clearing of natural spaces and mangroves, and the reclamation of wetlands to build tourist infrastructure; but also through an increase in levels of pollution and the over-exploitation of resources. Some 80% of the mangroves on the British islands have been destroyed, mainly to make way for construction of tourist infrastructures (see Box 2.16).

Alien invasive species

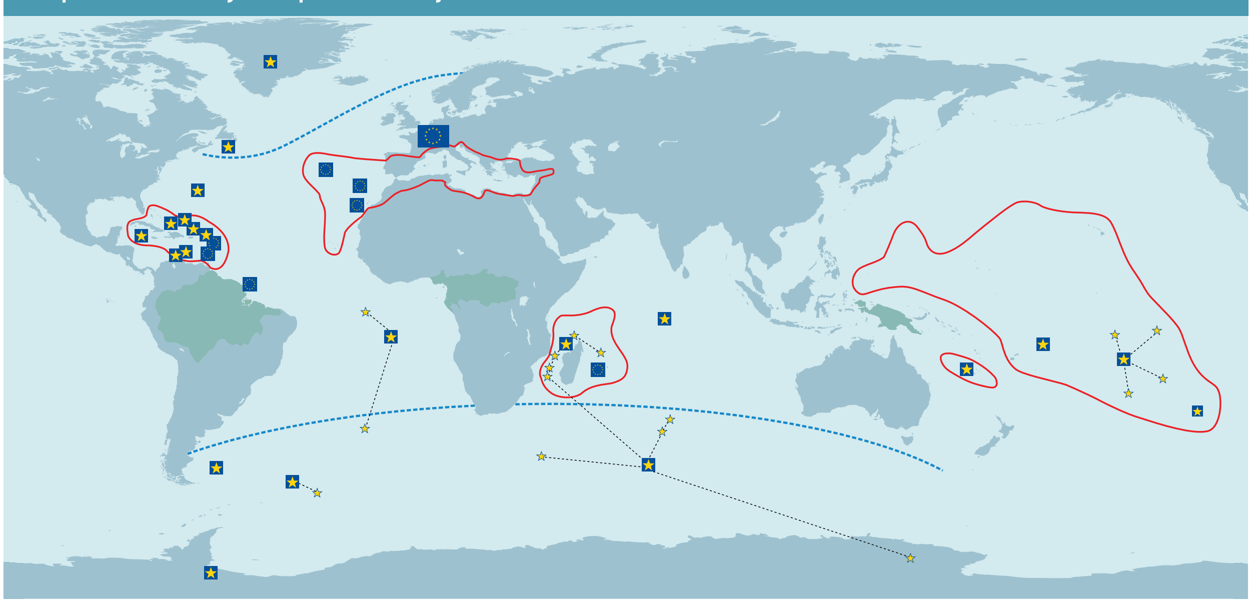
Alien invasive species are currently the single largest cause of species loss in island ecosystems (GISP 2008). Island animal and plant populations have been severely affected by the introduction of new predators or competitors against which they have not developed sufficient power of resistance. There are about 2,200 exotic plant species on the Reunion Island, 1,400 in New Caledonia, 1,700 in French Polynesia and 1,200 in the Antilles (Soubeyran, 2008). Some of these species are particularly aggressive and cause severe ecological damage which sometimes has serious economic, social and public health repercussions. In Bermuda, for example, an accidental introduction of the Juniper Scale Insect (*Carulaspis juniper*) in the late 1940s

Box 1.1: Biodiversity Hotspots

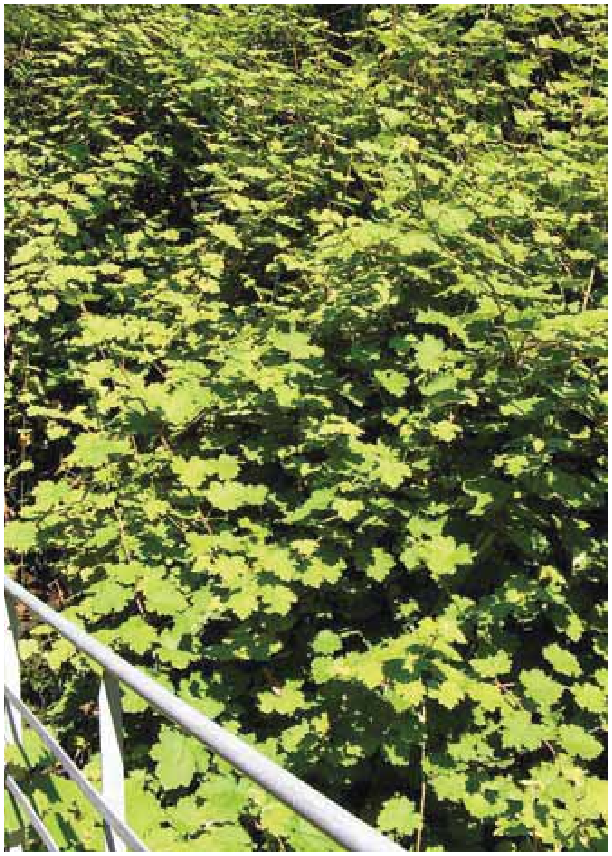
Life on Earth is facing a crisis of planetary proportions; global biodiversity is disappearing at a rate 100 to 1,000 times faster than the historical rate of disappearance. Massive extinctions on such a scale have only taken place five times in the history of our planet; the most recent to date was the Cretaceous-Tertiary crisis 65 million years ago, which ended the reign of dinosaurs. Today, scientists talk of a sixth mass extinction, with humans responsible for this ecological crisis (Wilson, 1994). Faced with this alarming development, it is crucial to identify priority zones for conservation throughout the world in order to try and save the maximum number of species. In 1988, the biologist Norman Myers, proposed the concept of "biodiversity hotspots", geographical zones where the biodiversity is both richest and most threatened (Myers 1988). Thirty-four biodiversity hotspots have now been designated throughout the world. They are home to about 60% of all terrestrial life forms on the planet; they are very limited in area, and represent only 2.3% of land areas. In these zones, some 50% of the plant species and 42% of species of vertebrates are endemic. Each hotspot is also subject to external threats; these regions have already lost at least 70% of their natural plant cover (Biodiversity hotspots 2008).

No less than 20 of the 28 overseas entities of the European Union are situated in these biodiversity hotspots. They are "The Caribbean Islands", "Madagascar and the Indian Ocean Islands", "Micronesia and Polynesia", "Mediterranean Bassin" and "New Caledonia". It is worth noting that New Caledonia is a hotspot in its own right, which testifies to its extreme biological wealth and its great vulnerability.

Map 2: Biodiversity Hotspots and Major Wilderness Areas



Biodivesity Hotspots covered by the EU overseas territories (in red) and Major Wilderness Areas (in green)



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The Invasive Bramble *(Rubus alceifolius)* spreads rapidly on Réunion Island

caused the death of 96% of the endemic Cedar forest (Ward, personal communication). In French Polynesia, the predatory *Euglandina rosea* snail, introduced as part of the biological struggle against the Giant African land snail, another invasive species, has led to the extinction of 59 species of endemic snails (Meyer and Florence, 1996). In Tahiti, two-thirds of the land area has been taken over by the ornamental *Miconia calvescens* plant whose mono-specific formations have replaced the island's indigenous forests. Rats, introduced when the islands were discovered by Polynesians, exert strong pressure on the indigenous birds of many islands, like the Monarch birds of French Polynesia or the Petrels of the sub-Antarctic islands. Herbivorous species, like wild pigs, goats and sheep and even rabbits, place stress on the indigenous plants of most of these islands, and seriously perturb the ecosystems. Rabbits in Kerguelen have caused the decline of a species of local cabbage, the Kerguelen cabbage (*Pringlea antiscorbutica*).

Over-exploitation of species

Over-exploitation of live species and natural resources, through fishing, hunting and wood extraction, remains a serious problem in most of the overseas ecosystems. Over-fishing threatens 60% of the coral reefs of the Caribbean (WRI 2005). Intensive poaching remains a problem for marine turtles on most of the tropical islands. Historically, exploitation of the forests has destroyed a large section of the Macaronesian Laurel forests; these are ancient mountain forests home to an exceptional diversity (see Box 5.5).

Pollution

Most of the natural ecosystems in the European overseas territories are affected by chemical and organic pollution of the air, water and soils. Chlordecone, an insecticide widely used in the Caribbean banana plantations until 1993, led to serious pollution of the water tables and lasting contamination of the soils of the French Antilles. Land-based sedimentation, caused by widespread soil erosion, is a serious problem in the Mayotte lagoon. Similarly, 80 to 90% of the waste water discharged into the ocean in the Caribbean and the Pacific is not treated; pollution of this type constitutes a direct threat to marine ecosystems (UNEP, 2006).

Climate change

Although recognised only relatively recently as a threat to biodiversity, climate change is fast becoming an equally, and possibly even more important conservation challenge, according to some scientists (Thomas et al., 2004). Island ecosystems are particularly vulnerable to climate change, because the biological populations of insular species are generally small, very localized, with limited means of migration, and often highly specialized. They are thus easily driven to extinction. Also, island ecosystems, like coral reefs, are often fragile and very sensitive to changes in their environment. Significant changes in temperatures, tropical storms, and sea levels have already been observed in the overseas entities of the European Union. Major impacts have already been recorded; such as coral bleaching or the erosion of some coastlines, and predictions about future impacts of climate change on the island ecosystems of Europe are alarming (see Section 1.4).

Richard Carter

Overfishing threatens 60% of the coral reefs of the Caribbean

Reality of Climate Change

1.3

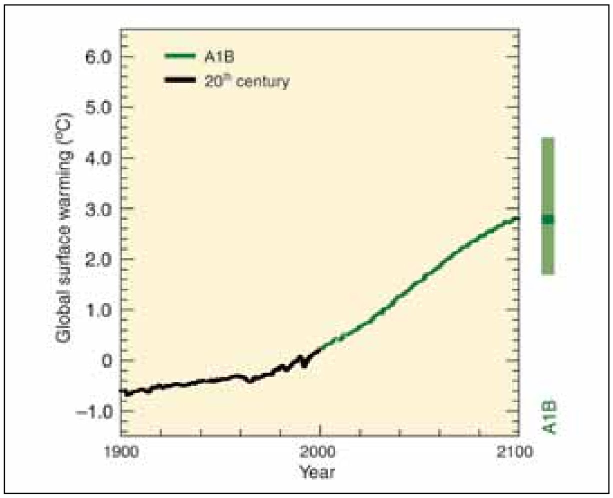
Climate change is defined by the United Nations Framework Convention on Climate Change (UNFCCC) as *"a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods"*.

1.3.1 Global warming

In 2007, members of the Intergovernmental Panel on Climate change (IPCC) (see Box 1.2) stated that human-induced warming of the global climate system was unequivocal. They further noted that increases in average air and ocean temperatures had already been observed throughout the world.

Global temperatures have increased by an average of 0.74°C [+ 0.56°C to + 0.92°C] in the last 100 years (1906-2005). This increase appears to have accelerated since the 1970s (IPCC, 2007). Indeed, 11 of the last 12 years (1995-2006) figure among the 12 hottest years since records of surface temperatures began (1850). These observations are simply a snapshot of a major climate deregulation that is on the verge of affecting the whole planet.

The IPCC predicts that average global temperatures may increase by a further 2.8°C [+ 1.7°C to + 4.4°C] between now and the end of the century (see Graphic). This warming will have extremely important physico-chemical consequences, such as changes in precipitation levels, changes in wind patterns, acidification of the oceans, and ice melt, and thus will affect all ecosystems and societies.



World temperature increase over the last century and IPCC A1B projections for the next century (IPCC 2007)

Box 1.2: Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate change (IPCC) was established in 1988, at the request of the G7 (group of seven industrialized nations), by the world Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). It brings together some 2,300 scientists from 130 countries, from research centres, universities, businesses and associations. Its role is to "assess the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change». It does not undertake research or monitor the evolution of climate change indicators; its assessments are based on scientific and technical publications whose scientific value has been widely endorsed. The first report of the IPCC was published in 1990; it already formulated important conclusions about future climate change. Other detailed reports have been published at 6-year intervals, in 1995, 2001 and 2007; each successive report on observed and projected climate changes is increasingly alarming. The documents produced by the IPCC serve as a reference for international negotiations on greenhouse gases. In 2007, the Nobel Peace Prize was awarded to the IPCC (jointly with Al Gore, former Vice-president of the United States), in recognition of the importance of the struggle against climate change for maintaining peace among nations.

World Economic Forum

Rajendra Pachauri, Chairman of the Intergovernmental Panel on Climate Change

1.3.2 Nature of the problem

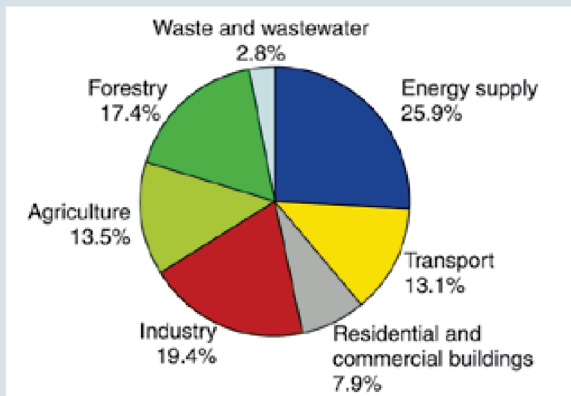
According to the majority of scientists, the global warming observed during the last few decades can be attributed to greenhouse gas emissions resulting from human activities. On 2 February 2007, IPCC experts (see Box 1.2) confirmed that the probability that global warming was the result of human activities was greater than 90%.

The greenhouse effect is a natural phenomenon. So-called "greenhouse gases" trap part of the infra-red radiation emitted by the Earth into the atmosphere thereby increasing the temperature of the lower atmosphere (troposphere). Without this the surface temperature of the Earth would be on average 33°C lower, or -18°C. However, this phenomenon has increased in magnitude in recent years, because of an important increase in the concentrations of human-made greenhouse gases. In particular, the volume of carbon dioxide (CO_2), which occurs naturally in the atmosphere in very weak concentrations, has increased considerably in the last two centuries. The atmospheric concentration of CO_2 has gone from 270 ppm (parts per million) in 1850, at the start of the industrial revolution, to 380 ppm today. These emissions have increased radically over the last 30 years; they rose by 80% between 1970 and 2004. In 2020, the concentration of CO_2 could reach 420 ppm according to the IPCC (IPCC, 2007).

Islands are particularly at risk from climate change yet, overall, they bear limited responsibility for the problem. The Pacific islands, for example, are home to 0.12% of the global population and are responsible for 0.003% of CO_2 emissions (IPCC, 2007). However, most of the overseas European islands have relatively high per capita emissions of CO_2, similar to the European Union average of 7.5 tonnes of CO_2 per inhabitant per year, and sometimes even more. Emissions have reached 18.7 tonnes per inhabitant in Aruba and 39 tonnes per inhabitant in the Netherlands Antilles (MDGI, 2008) (see Table 1).

Box 1.3: Activities Responsible for Global CO_2 Emissions

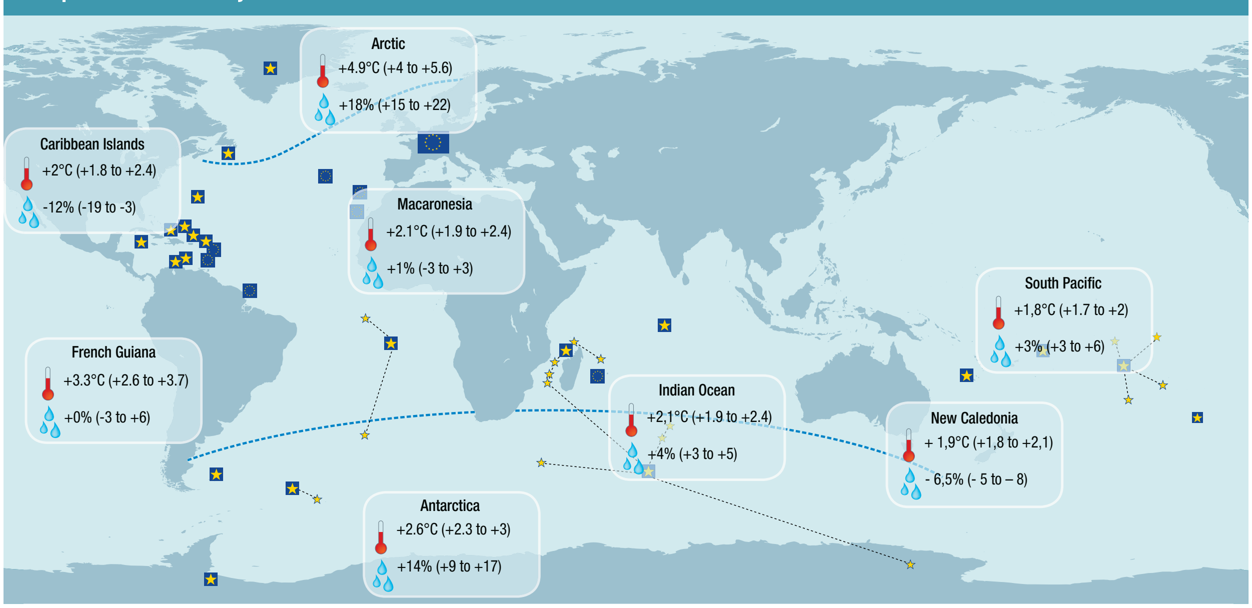
Fossil fuels (oil, coal or gas) are the main source of carbon in the atmosphere. Fossil-based energy production, which accounts for 27% of emissions, is the human activity responsible for the largest global emissions of atmospheric CO_2. This is closely followed by industry, responsible for 25% of emissions (see Graphic). Road, land and air transport are responsible for 17% of CO_2 emissions, making the transport sector a very important contributor to climate change. Air travel in particular is extremely polluting; airplanes emit 30 times more CO_2 than trains per person over the same distance. However, hydrocarbons are not solely responsible for carbon emissions. Deforestation, which accounts for 22% of emissions, is also an important source of CO_2. Deforestation is continuing at an alarming rate, with 13 million hectares of forest destroyed globally every year. The disappearance of forests leads to the release of the carbon stored in their biomass and in the soils. Thus, as well as being a major cause of biodiversity loss, deforestation is also in large part responsible for climate change (IPCC, 2007).



World CO_2 emissions per economic activity (IPCC 2007)

1.3.3 Observations and simulations for overseas Europe

Map 3: Climate Projections for the EU Overseas Entities



Average climate projections for 21 global models with uncertainty range in brackets (25 / 75 % quartiles). Projected changes in temperatures in °C and in precipitations in % from 1980-1999 to 2080-2099 (A1B scenario - IPCC 2007).

Box 1.4: Scenario A1B

In order to formulate its climate projections, the IPCC has put together a series of different CO_2 emissions scenarios based on global economic development and environmental trends (B1, A1T, B2, A1B, A2, and A1F1). Scenario A1B has been endorsed by the International Energy Agency (IEA) as the most likely scenario. Under this scenario CO_2 emissions increase until 2050 (due to rapid global growth primarily powered by fossil fuels); they subsequently slow down and eventually there is a drop in emissions after this date (due to greater use of clean energy solutions). The climate projections presented in this document are based on scenario A1B.

Rising temperatures

Significant warming is expected to take place throughout the overseas entities of the European Union, but with important variations between the different geographical areas. In the Caribbean, the Indian Ocean, the South Pacific and Macaronesia, temperature increases are predicted to be slightly lower than the global average with a rise of approximately +2°C. In French Guiana, the increase is expected to be greater, with projections of +3.3°C [+2.6 to +3.7°C]. This is because continents warm faster than the oceans, on account of their reduced thermal inertia. Finally, temperatures in the Arctic are predicted to rise considerably, and at a much more rapid rate than in the rest of the world. Climate models point to a probable increase in temperatures of 4.9°C [+4 to +5.6°C] in this region.

Change in precipitation patterns

Since the 1970s, longer and more intense droughts have been observed throughout the planet, and especially in the tropical and sub-tropical areas. This increased dryness is the result of higher temperatures and lower levels of precipitation. This trend has become apparent in the Caribbean region and in New Caledonia, which have experienced a significant decrease in precipitation over the last few years (see sections 2.1 and 4.3); while the remainder of the European overseas entities have experienced increasing volumes of precipitation.

In the future, the IPCC predicts an increase in the volume of precipitation in the higher latitudes, and a decrease in most of the sub-tropical regions (by about 20% between now and 2099). In the Caribbean, the predicted trend points to an average decrease in annual precipitation of 12% [-19 to -3]. Conversely, a slight increase has been predicted for the Indian Ocean and the South Pacific, with annual averages of +4% [+3 to +5] and +3% [+3 to +6] respectively. A greater increase is foreseen in the Polar Regions, with predictions of +14% [+9 to +17] in Antarctica and +18% [+15 to +22] in the Arctic.

Intensification of tropical cyclones

All observations indicate that there has been an increase in the intensity of hurricanes in the North Atlantic since the 1970s; this coincides with rising sea temperatures (see section 2.1).

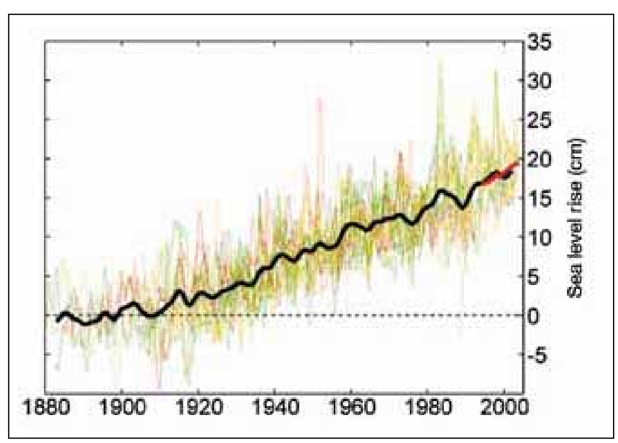
Using all the different models, the IPCC predicts an intensification of tropical cyclones throughout the tropical regions, with stronger winds and more abundant rainfall, resulting from a warming of the surface temperature of the tropical seas. However, it has not yet been possible to predict changes in the frequency of these cyclones (IPCC, 2007).

NOAA

Hurricane Dean in the Caribbean Sea on August 20 2007

Rising sea levels

Rising sea levels, which have been observed throughout the world in the last few years, are a direct consequence of global warming. They are primarily due to the thermal expansion of increasingly warm oceans, but also to melting of the glaciers, ice shelves and polar ice caps. Globally, the sea's level has risen by about 20 centimetres since 1900 (see Graphic). The rate of increase seems to be accelerating; it was of the order of 1.8 mm/year [1.3 to 2.3] after 1961 and has risen to 3.1 mm/year [2.4 to 3.8] since 1993 (IPCC, 2007).



Robert A. Rohde, Global Warming Art Project.

Recent sea level rise from 1880 to 2000. Average for 23 tide gauges scattered worldwide (black curve) and satellite altimetry (red curve).

The IPCC predicts a further average increase in sea levels of 0.35 metres [+0.23 to +0.47 metres] between now and 2099. However, these estimates are on the low side because they only factor in thermal expansion of the oceans, but they do not include the possible effects resulting from the melting of the polar ice caps (IPCC, 2007). A similar increase is predicted throughout most of overseas Europe, though with variations depending on the region.

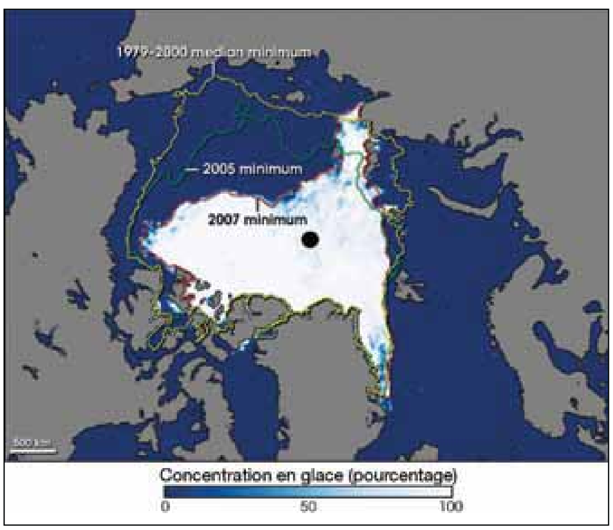
Ice melt

Changes in the ice shelf which surrounds Greenland are among the best indicators of the impacts of climate change. In 1978 its surface area at the end of summer (September) was about 7 million km²; by 2005 this had dropped to 5.32 million km² and by September 2007 it had fallen to 4.13 million km², or 40% of its original surface area (NASA, 2007). The staggering 2007 record is the largest decrease ever recorded. In the space of two years, between 2005 and 2007, the surface area reduced by more than one million km² or an area five times the size of the United Kingdom. These results outstripped all the IPCC climate models for the same year (see Box 7.1). At the same time, mountain glaciers and ice coverage diminished in both hemispheres.

Drop in thermohaline circulation

On the basis of recent simulations, the IPCC has predicted a probable 25% [0 to –50 %] reduction in thermohaline circulation during the course of this century (IPCC, 2007).

Thermohaline circulation refers to the loop which begins when the dense and well-oxygenated cold waters of the North Atlantic (that have been cooled by the Canadian winds), sink to the sea bed. These waters head south at a depth of close to 3 kilometres. When they reach the tropics they are warmed and come back up to the surface as they head back



Minimal sea ice surface in 2005 and 2007 compared to the average minimal surface from 1979 to 2000

to the north where they are once again cooled. This circuit helps to redistribute the heat of the tropics throughout the planet. If the surface layer of water heats up, the difference in density between the surface waters and the deeper waters becomes more marked, and the rising currents are not strong enough to break through to the surface. Global warming is thus causing a drop in the ascending currents and slowing thermohaline circulation. These changes could have profound influences throughout the world.

Change in wind patterns

Climate change could also lead to a change in atmospheric air circulation (circulation of the layer of air surrounding the Earth). In the last few decades, for example, the Anticyclone of the Azores has moved east (Cassou et al., 2004), resulting in a positive North Atlantic Oscillation (NAO+). This phenomenon results in an important change in wind patterns throughout the North Atlantic. In Macaronesia, this change has led to a drop in the cold north-easterly trade winds, and an increase in the strength of the east winds blowing from Africa.

Acidification of the oceans

The increase in the level of carbon in the atmosphere caused by human activities since 1750 has led to a general acidification of the oceans. A drop of 0.1 units in the global average PH level has been observed. IPCC models point to a further drop in global oceanic surface PH levels of between 0.14 and 0.35 units between now and the end of the century (IPCC, 2007).

Intensification of the El Niño phenomenon

El Niño is a natural climatic phenomenon that occurs every four to eight years. It is caused by a change in the atmospheric pressure above the Pacific Ocean. It is characterized by a warming of the surface waters in eastern and central tropical areas of the Pacific Ocean; it influences atmospheric currents and thus ecosystems throughout the world. It can lead to droughts in certain regions of Asia and the Western Pacific, or to harsh winters and flooding on the North American continent. The exceptional climate conditions brought about as a result of the El Niño weather system provide a glimpse of the potential impacts of climate change in the future.

The impact of climate change on the occurrence of the El Niño phenomenon remains uncertain, despite the fact that two recent events, in 1982/1983 and in 1997/1998, proved to be the most extreme in the last century and probably in the last 400 years (BE, 2008). Notwithstanding, by leading to an increase in temperatures and a drop in precipitation in some regions, climate change could considerably exacerbate the impacts of the El Niño phenomenon in coming years.

Impacts of Climate Change on Biodiversity

1.4

Climate change will have irreversible effects on biodiversity. According to the IPCC, some 20 to 30% of known species will be at greater risk of extinction if global warming exceeds 1.5 to 2.5°C (in relation to 1980-1999 levels). If the average global temperature increase exceeds 3.5°C, all models suggest that a large number of species will be driven to extinction (from 40 to 70% of all known species) across the globe (IPCC, 2007). The biodiversity of the overseas entities of the European Union is especially vulnerable.

1.4.1 Impacts on terrestrial ecosystems

Climate-sensitive forests

Climate and forests are intimately linked. Forest biomass captures and stores C02, thereby playing an essential role in the global carbon cycle. As noted above, deforestation is responsible for approximately 22% of global carbon emissions and contributes substantially to climate change. Forests are also among the first victims of climate change. As a general rule, forests are negatively affected by rising temperatures, changes in precipitation levels and extreme weather events. A general deterioration of forests will create a vicious circle whereby $C0_2$ emissions are likely to increase which in turn will result in greater deregulation of the climate and so on.

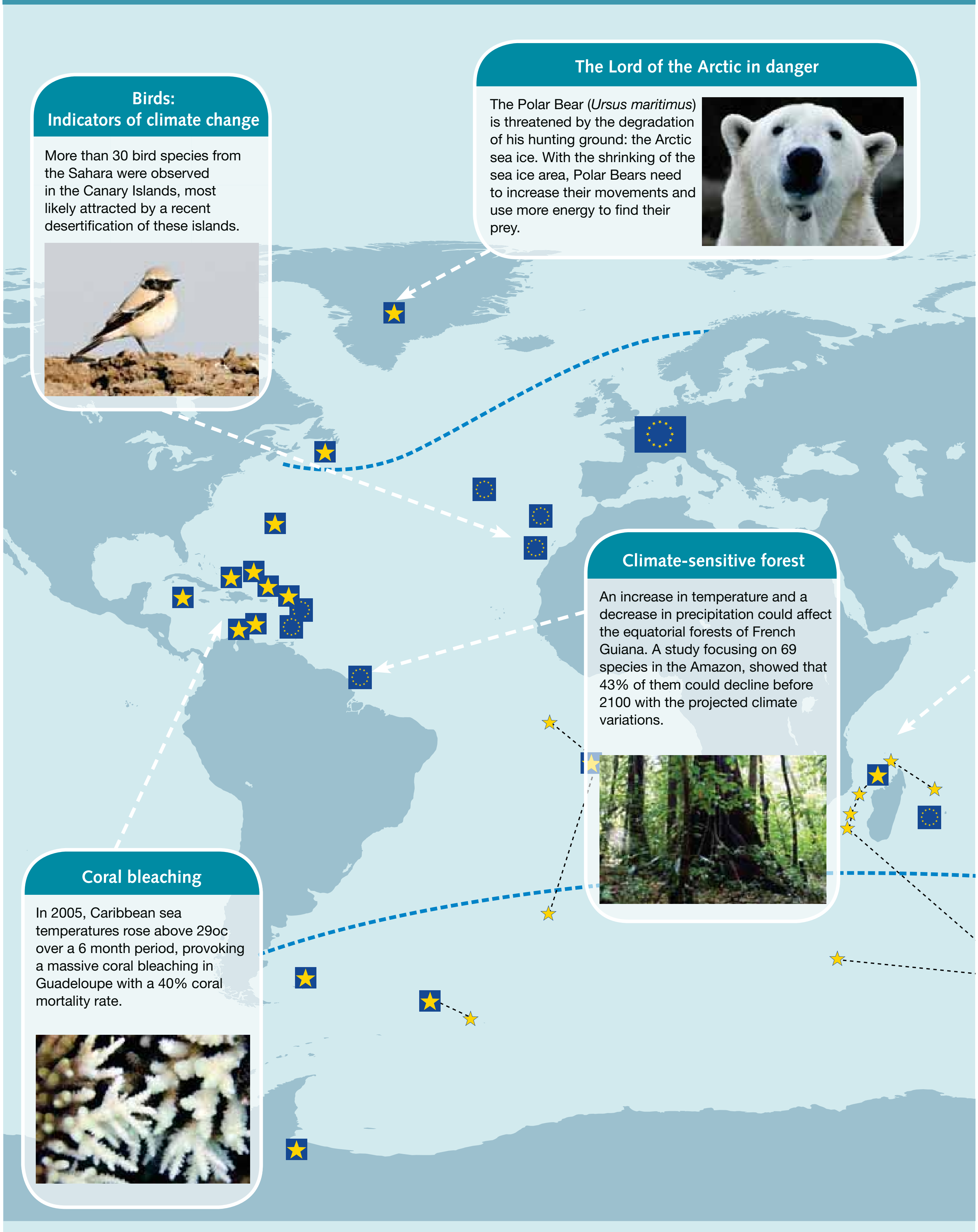
In the Amazon and in French Guiana in particular, ecosystem modelling based on climate projections indicates that a drop in levels of precipitation could bring about a potential decline in the primary productivity of the tropical forest (Cox, 2004) (see Box 6.2). Several studies indicate that the more intense droughts that will affect these ecosystems run the risk of increasing their vulnerability to forest fires (Nepstad, 2004). Finally, another simulation for the region shows that 43% of species of seed plants studied could disappear between now and 2095 because of a potentially too great shift in their spatial distribution (Miles, 2004) (see Box 6.3).

Forest ecosystems on volcanic islands are also very vulnerable to changes in climate conditions. The climate in these mountainous islands is often divided into bio-climatic zones that range from a dry-bio-climate at sea level to a hyper-humid bio-climate at the mountain summits. Increases in temperatures and a drop in levels of precipitation will cause the bio-climatic zones to rise toward higher altitudes, bringing about the migration of species towards higher altitudes. This migration will pave the way for the spread of invasive species to the detriment of more fragile indigenous species. The high altitude rainforests, which are generally home to a great wealth of endemic species, are the most vulnerable ecosystems, because they will be unable to migrate towards higher altitudes. Models showing the potential impacts of climate change on high altitude forests have been developed in Martinique and French Polynesia (see Boxes 2.3 and 4.2). Conversely, in Macaronesia, the Laurel forests (mountain forests typical of the region) will likely migrate towards the lower reaches of their area of spatial distribution as a result of a drop in the trade winds resulting from climate change. This will have equally serious consequences for these ecosystems

Jérôme Petit

Endemic mountain vegetation in Moorea, French Polynesia

Map 4 : The Impacts of Climate Change on Biodiversity in the Overseas Entities of the European Union



Birds: Indicators of climate change

More than 30 bird species from the Sahara were observed in the Canary Islands, most likely attracted by a recent desertification of these islands.

The Lord of the Arctic in danger

The Polar Bear (*Ursus maritimus*) is threatened by the degradation of his hunting ground: the Arctic sea ice. With the shrinking of the sea ice area, Polar Bears need to increase their movements and use more energy to find their prey.

Climate-sensitive forest

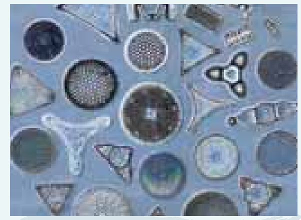
An increase in temperature and a decrease in precipitation could affect the equatorial forests of French Guiana. A study focusing on 69 species in the Amazon, showed that 43% of them could decline before 2100 with the projected climate variations.

Coral bleaching

In 2005, Caribbean sea temperatures rose above 29oc over a 6 month period, provoking a massive coral bleaching in Guadeloupe with a 40% coral mortality rate.

Impacts on phytoplankton

Satellite imagery shows that ocean phytoplankton have declined as much as 30% in some areas of the South Pacific over the last 10 years due to ocean temperature rises.

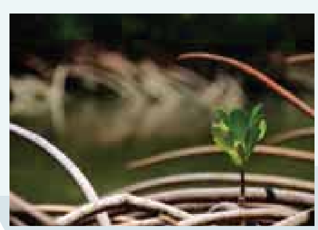


Turtles threatened

Beach erosion results in the loss of sea turtles nesting habitats, and an increase in the sand temperature could disrupt the sea turtle male/female ratio, which is determined by the temperature at which eggs incubate.

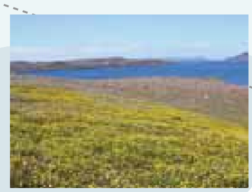
Mangrove destruction

About 13% of the mangrove areas in the South Pacific could disappear before 2100, with a global sea level rise of 88 centimetres.



A surge in the number of invasive species

Climate change favoured the expansion of the invasive Dandelion (*Taraxum officinale*) on Kerguelen Island, and of a Blue Fly (*Calliphora vicina*) on the Crozet archipelago



Ykon White Light

The King Penguins (*Aptenodytes patagonicus*) from South Georgia are threatened by a phytoplankton abundance decrease in the region

as the areas at lower altitude are largely developed urban areas and the forests will not be able to establish themselves (see Box 5.5).

Finally, a drop in precipitation levels in New Caledonia will increase the risk of forest fires and pose a serious threat to the last vestiges of dry forest; these are biodiversity-rich ecosystems whose coverage has been reduced to 1% of their original surface area (Papineau, communication personelle) (see Box 4.8).

A surge in the number of invasive species

With globalization, the growth of international trade and the increase in journeys and exchanges, alien invasive species have spread widely and are now exerting considerable pressure on natural ecosystems. Climate change could significantly exacerbate this problem.

A change in climate conditions could make some ecosystems more hospitable to certain alien invasive plant or animal species. For example, warming observed in the Kerguelen archipelago since the 1970s has facilitated the spread of the Blue blowfly (*Calliphora vicina*) and two species of plant, a dandelion (*Taraxacum erythrospermum*) and a stellaria (*Stellaria alsine*), all of which pose a considerable threat to the local flora (see Box 7.7).

At the same time, climate change could also destroy some of the physical barriers that prevent the spread of invasive species. For example, glacial melt in the Polar Regions could enable invasive species to colonize new, previously inaccessible habitats. This has happened with rats in South Georgia that are beginning to affect the seabird populations (see section 7.5).

Finally, a change in wind patterns could lead to the spread of wind-borne invasive species. In the Canary Islands, plagues of Pilgrim crickets (Locusts) could become more frequent as a result of the strengthening of the south-westerly winds from Africa, which are expected with higher temperatures (see Box 5.1).

Birds: indicators of climate change

Highly sensitive to climate and meteorological conditions, birds are excellent indicators of global changes in climate (Berthold et al., 2004). Several studies indicate that there have been recent changes in the seasonal migration patterns of birds throughout the world (Lehikoinen et al., 2004). Birds' egg-laying and migration periods are intimately linked to changes in seasons, and a change in global climate conditions is bringing with it serious modifications in the biological cycles of these species, and often altering their reproductive and survival capabilities (Sanz et al., 2003). Of 119 species of migratory birds studied in Europe, 54% have already showed signs of regular or even severe decline between 1970 and 2000. Climate change is believed to be one reason for this decline (Sanderson et al., 2006).

Migratory birds are also highly sensitive to tropical storms and cyclones that hinder their migration or change the course of their migratory paths. This is the case of migratory birds in the Caribbean (see Box 2.18). Tropical storms also affect terrestrial birds by temporarily destroying their refuges or their food resources. In the Cayman Islands, for example, hurricane Ivan had a very severe impact on local bird populations (see Box 2.13).

In Antarctica, a drop in the abundance of phytoplankton caused by climate change is severely affecting those seabird populations that depend upon it such as King Penguins, for example (see Box 7.8).

Finally, changes in climate conditions can modify the spatial distribution of some species of birds with indirect consequences for all ecosystems. The desertification of the Island of Fuerteventura in the Canaries, for example, might have led to the establishment of several species of exotic birds, hitherto restricted to the Sahara desert region (see Box 5.2).

Other terrestrial species

The number of species at risk from climate change is huge, and it would be impossible to list them all. However, some particularly threatened iconic species from the European Union overseas entities, deserve a special mention.

The polar bear, which inhabits the Artic Shelf, recently became an icon for the impacts of climate change on biodiversity. Indeed, polar bear populations are seriously threatened by a rise in temperatures in the Arctic which, by leading to a thaw in the Arctic Shelf, are melting their habitats (see Box 7.2). In French Polynesia, several species of endemic snails are threatened by the territorial expansion of predatory species in their area of spatial distribution, caused by a rise in temperature (see Box 4.3). The "mountain chicken" of Montserrat, one of the largest frogs in the world, is threatened by the potential spread of a disease which afflicts several amphibian species throughout the world, and which is spreading thanks to changes in climate conditions (see Box 2.22). Finally, populations of Caribbean endemic bats, often the only indigenous land mammals on these islands, are threatened by the intensification of tropical storms (see Box 2.23).

1.4.2 Impacts on coastal ecosystems

All coastal ecosystems, especially those at low altitude, are at risk from rising sea levels and from possible changes in the strength and number of tropical storms. Low-lying coral islands (or atolls) and many high island coastal communities live only a few metres above sea level and are vulnerable to erosion and even submersion (see Box 4.1).
Erosion is already an important issue in many coastal communities and islands (e.g. Chagos archipelago and Wallis and Futuna - see sections 3.4 and 4.4) and the potential for sea level rise to increase this problem is great.

Many tropical coasts are protected from wave action by living coral reefs and likewise the shores which lay behind these reefs are often composed of coral reef debris (see Box 2.14). As such, any change in coral reef system health, structural integrity or productivity caused by pollution, poor management and/or climate change (see section 1.4.3) is likely to exacerbate coastal erosion.

Beach erosion

Rising sea levels have already led to erosion of beaches throughout the world. Since 1900 the global sea level has risen by about 20 centimetres. The general effect of this rise on beaches is not fully understood, but it had serious impacts on the beaches of some regions. A study of 200 beaches on nine Caribbean islands conducted between 1985 and 1995 revealed that 70% of the beaches studied had been eroded (Cambers, 1997). Similarly, in the Pacific region, beach erosion is a common and important issue and continued sea level rise is expected to contribute added stress to these beaches.

Furthermore, the potential intensification of tropical storms is also likely to exacerbate erosion. In Anguilla, the passage of hurricane Luis in 1995 led to an average loss of 1.5 metres of beach throughout the island, with losses of up to 30 metres being recorded in some areas (UNESCO 2003) (see Box 2.20). Whilst shorelines are resilient to natural stress events such as storms if these become more intense or more frequent or if beaches are already stressed through reef degradation this natural regenerative capacity can be overwhelmed, resulting in chronic ongoing erosion and loss of land.

Changes to the state of the beaches have important repercussions for the fauna and flora that inhabit these environments, particularly for the marine turtle populations that come to lay their eggs. Eventual erosion of the beach berm (the highest part of the beach) leaves low laying land and terrestrial communities behind this berm very vulnerable to wave incursions and salt water flooding which inturn can threaten vegetation, freshwater resources and human wellbeing.

John Turner

Eroded beach in Chagos, likely because of a recent sea level rise

Adrien Cretin

Mangroves are threatened by sea level rise and tropical storms intensification

Mangrove destruction

Approximately 20% of the global mangrove area has been destroyed since 1980, largely due to deforestation, building construction and aquaculture (FAO, 2008). Yet, mangroves are ecologically, culturally and economically very important. They provide indispensable fish nurseries (see Box 2.6); they filter coastal pollution and provide wood for local populations. They also play an important role in protecting the coasts from tropical storms and tsunamis; by passing through 200 metres of mangroves, a wave loses 75% of its power (FAO, 2008). Rising sea levels caused by climate change represent a new threat to mangroves. A recent study on the vulnerability of 16 Pacific island States and territories home to indigenous mangroves concluded that close to 13% of the area of mangrove cover is at risk (UNEP, 2006) (see Box 4.9).

The Caribbean mangroves are also threatened by the intensification of tropical storms: hurricane Hugo devastated 75% of the Red mangroves in Guadeloupe (Imbert, 2002) (see Box 2.1).

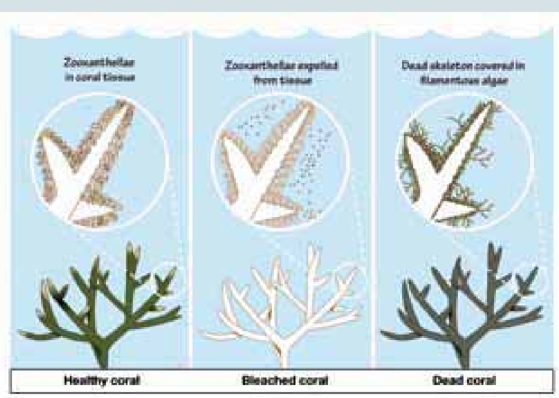
1.4.3 Impacts on marine ecosystems

Coral bleaching

Coral reefs are the most biodiversity-rich marine ecosystems. They only cover 0.2% of the surface of the oceans; yet they contain 25% of their species (Roberts, 2003). For this reason they are often dubbed the “rain forests of the sea”. Globally, close to 500 million people depend upon coral reefs for

Box 1.5: Coral Bleaching

Coral bleaching is the loss of colour in these organisms resulting from stress. Coral is the foundation of the reef ecosystems in tropical seas. It is made up of polyps (very simple small cylindrical animals that resemble sea anemones) living in symbiosis with single-celled photosynthetic micro-algae known as zooxanthellae. The latter need light to grow, and hence corals develop in shallow waters. It is the zooxanthellae that give coral their brown-green colours (other spectacular colours are mostly from the animal tissues). When they are exposed to stress, the corals expel their zooxanthellae, which gives them a lighter or completely white appearance, hence the term “bleaching”. This expulsion of zooxanthellae deprives the coral of a major source of energy that is normally supplied by the symbiotic algae; as a result the coral “starves”. Bleaching can result from many disruptions to the marine environment, but particularly from a noticeable warming of seawater temperatures combined with strong light. Following a bleaching event, the surviving corals may be re-colonized by the zooxanthellae of the same or different species. The symbiotic relationship can take several weeks, or even several months to re-establish. If the stress is prolonged, the corals might not be re-colonized by the micro-algae in time and will perish from starvation.



IUCN

Coral bleaching stages

their livelihoods, costal protection, renewable resources and tourism. Some 30 million people, including some of the poorest populations in the world, depend entirely upon coral reefs for their food (UNESCO, 2008). The goods and services provided by corals are estimated to contribute US$ 30 billion to the global economy annually (Cesar, 2003). Yet, coral reefs are also probably the most vulnerable ecosystems in the world. Today, it is estimated that 20% of the world's corals have already been destroyed, 24% are on the verge of disappearing, and a further 26% are in danger of disappearing in the future (Wilkinson, 2004). Indeed, the reefs are seriously affected by over-fishing, pollution, costal development, invasive species, epidemics and, more recently, coral bleaching and other impacts of climate change (IUCN, 2006).

Over the past 15 years coral bleaching, caused by climate change, has fast become the single greatest threat to these ecosystems (see Box 1.5). During the 1998 El Niño event, unusually high water temperatures over a prolonged period caused coral bleaching in more than 50 countries. The countries and islands in the west of the Indian Ocean were the worst affected, with an average mortality rate throughout the region of 30% (Obura, 2005). In the Chagos archipelago, the bleaching reached 95% in some areas (see Box 3.8). Similarly, in 2005, a major bleaching episode affected the Caribbean. Up to 95% of corals were bleached in parts of the Cayman Islands, Jamaica, Cuba and the French Antilles (Wilkinson & Souter, 2008). In Guadeloupe, this event caused high mortality among the corals that were already weakened by the pressure of other human activities (see Box 2.2). Indeed, coral resilience to bleaching depends on the general state of health of the reefs and the extent to which they are subject to other human pressures (see Box 1.6).

The 2.8°C increase in the temperature of the tropical waters between now and 2100 projected by the IPCC could mean that coral bleaching events like those of 1998 and 2005 become more frequent: every year or every two years in 2030-2050 (UNEP, 2006). Many scientists predict that corals are unlikely to remain abundant on reefs and could be rare by the middle of this century (Hoegh-Guldberg, 2005).

Box 1.6: The Resilience of the Corals Depends on the Health of the Reefs

Coral resilience is their capacity to recover following a period of stress. In the case of bleaching, resilience depends directly on the related human-induced pressures to which they are exposed, primarily pollution and over-fishing. Studies carried out in the Seychelles during the 1998 bleaching event pointed to a strong correlation between the recovery of the corals and coastal-water quality. The rate of recovery varied from 5 to 70% depending on pollution levels. The coral reefs that recovered most rapidly tended to be those situated in marine protected areas and in those coastal areas where levels of pollution were low (Wilkinson, 2002; UNEP, 2006). Ecological balance and biological diversity of the reefs are also important determinants of the resilience of corals. In particular, herbivorous fish and urchins play a very important role in the recovery of corals after a disturbance (Nyström and Folke, 2001): they eliminate the marine algae thereby preventing them from colonizing the degraded corals and facilitate the establishment of young corals. Over-fishing of herbivorous reef fish weakens the resilience of the corals to coral bleaching.

Very marked differences in levels of resilience have been observed among the corals in the overseas European entities. In the Indian Ocean, following the 1998 bleaching episode, coral mortality was very high among the polluted and degraded corals of Mayotte. Conversely, the level of recovery was much higher among the corals of the Chagos archipelago where human-induced pressures were much lower (see Box 3.8). Thus, while it will be difficult to prevent a warming of the waters in the short term, it is nonetheless possible to improve the resilience of the corals to bleaching by reducing the impacts of human activities.


OMMM

Bleached coral reef in Martinique in 2005

Rising temperatures are not the only consequences of climate change to imperil the corals. The reefs are also directly threatened by rising sea levels, intensification of tropical storms and acidification of the oceans. Healthy corals could adapt to a progressive rise in sea levels, but degraded corals will not be able to follow the water level. Tropical storms have a very important effect on the reefs, especially in those areas that are not adapted such extreme weather events. Hurricane Erica, for example, which battered New Caledonia in 2003, destroyed a large section of the reefs in the marine park in the south of this territory (see Box 4.7). Finally, the progressive acidification of the oceans could have damaging effects on marine organisms with shells, like the cold-water corals of Macaronesia, but also on urchins throughout the marine ecosystem (UN, 2006) (see Box 5.6).

Declining fish stocks

Approximately 80% of species fished throughout the world are exploited beyond their capacity to regenerate (UNEP, 2006). Fish stocks are already at historically low levels. Climate change, which is degrading their sources of food and/or changing their spatial distribution, is yet another major threat to global fish populations.

stuandgravy

Green Turtles (*Chelonia mydas*) are threatened by beach erosion and sand temperature increase

A general deterioration of the corals, and particularly bleaching episodes, could have an impact on those species of fish that depend upon coral for their survival. Two studies, carried out in the Seychelles and the Caribbean, indicate a significant decrease in the diversity and abundance of reef fish following the 1998 and 2005 bleaching episodes (see Boxes 3.8 and 2.21). A decline in these species poses a direct threat to their predators, fish or bird, and impacts upon the entire tropical ocean food chain.

Coral degradation is not the only threat to fish stocks. Pelagic fish are apparently also affected by a reduction in thermohaline circulation (globally important convectional sea currents), caused by climate change. This reduction leads to an important drop in the production of phytoplankton on which most pelagic fish depend, and leads to further drops in fish stocks in certain areas (see following paragraph). Approximately 75% of fishing zones are affected by the impacts of reduced thermohaline circulation (UNEP, 2006).
Finally, rising temperatures caused by climate change could also lead to a change in the spatial distribution of certain fish species. A recent study conducted in the North Sea analysed changes in the spatial distribution of several species of fish between 1977 and 2002. Of the 36 species studied, 21 species including the common sole (*Solea solea*) and the Atlantic cod (*Gadus morhua*), have migrated further north, in response to an increase in water temperatures of about 1.05°C (Perry, 2005). Some species have migrated up to 1,000 kilometres further north in less than 20 years (Quérot, 1998). In Macaronesia, migrations of southern tropical fish have recently been observed for the first time (see Box 5.7). Major movements of fish stocks could completely modify the equilibrium of marine food chains and lead to a decline in certain cold water species that will not be able to migrate to higher latitudes.

Marine turtles in danger

Marine turtles are directly affected by the impacts of human activities including the direct destruction of nesting sites, pollution, accidental capture in fishing gears such as nets and longlines, and poaching for meat and eggs. Today, all 7 marine turtle species are included in the IUCN Red List where they are listed as "critically endangered". Climate change brings an even more insidious threat which is likely to considerably hasten the decline of this species. Marine turtles are often used as a biological indicator to measure the impacts of climate change on the natural environment, because this phenomenon affects them throughout their entire life cycle (Lovich, 1996).

Turtles travel several thousand kilometres, across whole oceans, between their nesting sites and their feeding grounds. Climate change is likely to change global ocean currents and the migratory paths of turtles. A rise in sea levels and the intensification of tropical storms are likely to erode the beaches on which they lay their eggs (see Box 2.11). Finally, warming of nesting beaches could modify the male/female ratio of the eggs, which is determined by the temperature of incubation. In a scenario of warmer climate, the number of males could drop, which would affect the reproductive capacity of these species (see Box 3.5).

Impacts on phytoplankton

Phytoplankton is a single-celled alga that floats freely on the upper layers of the oceans. At the base of the marine food chain, phytoplankton serve as food for zooplankton (animal plankton), which in turn represent important food for numerous fish species. Phytoplankton plays a crucial role in the global carbon cycle because it accounts for approximately half of global photosynthesis. It sequesters a considerable quantity of CO_2 as organic material that is then stored in the oceans.

Several studies indicate that climate change, and in particular the resulting drop in thermohaline circulation, could seriously diminish phytoplankton biomass throughout the world. Recent observations from satellite imagery have shown that phytoplankton biomass has diminished by up to 30% in some regions of the South Pacific (Behrenfeld 2006) (see Box 4.13). Furthermore, reduction in the Antarctic seasonal sea ice could also reduce the production of certain species of phytoplankton that develop below the ice. This reduction could have important consequences for krill, a species of zooplankton similar to a small shrimp, which depends on this species of phytoplankton (see Box 7.5). Finally, phytoplankton with a calcium-based shell will be directly threatened by acidification of the oceans (Geelen, 1986).

Although most oceanic phytoplankton is likely to decline, some species could nonetheless see their numbers increase. This is the case of *Pyrodinium* for example, a species of phytoplankton responsible for red tides in the Caribbean and several other regions of the world. This toxic phytoplankton proliferates by flowering and reaches such concentrations that the waters become completely discoloured. Red tides are a natural phenomenon, but one which has become far more frequent in the last 20 years (Patz, 2000). This increase has been attributed to a warming of the water temperatures resulting from climate change. In the Canary Islands, for the first time in 2004 waves of brown algae were observed, caused in all likelihood by the unusually high temperatures experienced by the archipelago that year (see Box 5.3).

Other microscopic algae in the tropical regions could take advantage of climate change-induced degradation of the corals to develop. For example, dinoflagellates, and particularly *Gambierdiscus toxicus* which causes “ciguatera” food poisoning. These algae proliferate on dead corals; they are closely monitored in the Reunion Island and in French Polynesia (see Boxes 3.2 and 4.5).

Mistermoss

Humpback whale (*Megaptera novaeangliae*) group feeding on krill in South Georgia

Vulnerable marine mammals

Marine mammals, and in particular cetaceans, are under threat from human activities including pollution, poaching or maritime activities. Poaching alone is responsible for the death of 300,000 cetaceans a year, which represents about 1,000 individuals each day (WWF, 2007). All 81 species of cetaceans inventoried in the world are included in the IUCN Red List. Two of them are “critically endangered” and seven “endangered”, one of which is the Blue Whale (*Balaenoptera musculus*).

Climate change brings new threats for these animals. Some threats are direct: for example, rising temperatures could force certain species to migrate further north in search of climate conditions to which they are best adapted. However, sometimes, species will not be able to migrate. Furthermore, climate change is likely to change the availability and abundance of food for cetaceans. Whales, in particular, have a highly specialized diet. Krill, a zooplankton that closely resembles the shrimp, is the main food source for several species of large whale. It is concentrated in very localized geographical areas of the Polar oceans, and only found in highly specialized environmental conditions. Climate change, by causing reduction in the Antarctic seasonal sea ice, could trigger a decline in phytoplankton which could in turn affect the abundance, distribution and hatching period of krill, with very serious consequences for the reproductive and survival capacity of cetaceans (WWF, 2007) (see Box 7.6).

Socio-Economic Implications

1.5

Sarah Sanders

Impacts of Hurricand Dean on coconut trees in the Caribbean

Climate change will have serious consequences on the well-being of human populations as a result of its direct physical impacts (such as heat waves, tropical storms or rising sea levels), but also through its impacts on natural resources. In his famous 2006 report, the British economist, Nicholas Stern, noted that if nothing is done to prevent climate change, the related economic losses of this scourge would be the equivalent of a 5 to 20% reduction in global GDP per year (Stern, 2006).

Damaged infrastructure

The number of violent hurricanes in the Caribbean has increased significantly over the last 30 years. An intensification of these extreme weather events will result in serious economic losses for the affected islands (see section 2.9).

A rise in sea levels will also have a major impact on infrastructure. In volcanic islands populations tend to be concentrated along the narrow, low-lying plains between the ocean and the steep mountains; while coral atolls rarely exceed a few metres above sea level. Simulation models showing the effects of rising sea levels have been carried out in French Polynesia and Wallis and Futuna, showing the potential impacts of submersion on the airport or settlements of these islands (see Box 4.11).

Affected agriculture

Agricultural activity contributes to global warming through deforestation to make way for cultivable land, but also through the emissions produced by the use of fertilizers and the methane gases given off by livestock. According to the FAO, the latter are even more harmful than emissions from automobiles (FAO, 2006). That said, however, this sector too will be one of the biggest victims of climate change. The significant drop in rainfall observed in several regions of the world will lead to a decline in crop harvests. In 2003, global cereal production declined considerably, resulting in a deficit of 93 million tonnes on global markets (USDA, 2003). This decline can be attributed in part to the droughts that affected a number of producing States that year. A recent study published in the journal Science showed that the southern African region could lose up to 30% of its maize production capacity between now and 2030 (Lobell et al., 2008). Similarly, global agriculture could be directly affected by a change in crop cycles brought about by temperature changes, an increase in the rate of erosion caused by heavier rainfall, the proliferation of invasive animal and plant pests, and a decrease in the area of available arable land caused by rising sea levels. The production of biofuels, as part of attempts to reduce dependence on fossil fuels, will lead to competition with traditional crops and also reduce the available area of arable land.

The European overseas agricultural sector has not been spared from this global threat. Tropical storms in the Caribbean have caused severe material damage to the agricultural sector of the region, estimated at some 115 million Euros in the case of the Martinique banana plantations which were entirely (100%) destroyed during the passage of hurricane Dean in 2007 (PECE 2006). Studies undertaken in the Caribbean indicate that the production of citrus fruits and root vegetables could also be affected by changes in climate (see Box 2.4). Finally, traditional Taro crops (a root vegetable which is a food staple in several Pacific islands), on the coast of Wallis and Futuna, were recently affected by rises in sea level (see Box 4.12). Subsistence agriculture is one of the most important pillars of the economies of tropical islands with largely rural populations. Climate change and its brutal effects on this sector, could seriously affect entire economies of these territories.

Threats to tourism

Tourism has recently become the most important pillar of the economies of most of the tropical islands of overseas Europe. This sector is also concerned by climate change, partly because it contributes to the problem¬ – 4 to 6% of global CO_2 emissions are attributable to tourism (UNWTO, 2007) – but also in part because it will be seriously affected by this phenomenon. Climate change could influence choice of destinations, through warmer summers or winters, or more extreme weather events. At the same time, because of the impact of tourism on the natural resources of islands, like beaches or coral reefs, climate change could affect the environment of tourist sites. Finally, tourist mobility could be limited by greenhouse gas emission reduction policies (Céron, 2008). For example, concerns about carbon emissions from airplane flights might discourage European tourists from visiting Pacific islands.

In Anguilla, the destruction of tourist infrastructure following the passage of hurricane Lenny in 1999 led to losses of US$ 75 million for the island's economy (see section 2.9). A survey of visitors carried out in Bonaire showed that 80% would not return to the island if the corals and beaches were degraded (Uyarra et al., 2005) (see Box 2.8). Finally, the Canary Islands could soon become too warm a destination for European visitors (see section 5.2).

Repercussions on fishing

According to a recent UN report, climate change will have a serious impact on global fishing. A decline in thermohaline circulation could lead to a drop in fish stocks of more than 75% in fishing zones (UNEP, 2006). In the North Sea, for example, a combination of climate change and over-fishing has led to a severe drop in cod stocks (Brander, 2006). However, fisheries in certain Polar Regions like Greenland are benefiting from ice melt and rising temperatures, which are improving the productivity of at least some fish stocks.

In tropical regions, degradation of the corals, which has significant consequences for reef fish populations, could indirectly damage the fishing sector. Studies show that subsistence fishing in the Caribbean has been severely affected by coral bleaching (see Box 2.21). Island traditions and cultures are indivisible from fishing activities, which account for a significant part of the economic activities in these territories.

Public health concerns

Climate change constitutes a new threat to human health. Variations and changes in climate are leading causes of death and illness through heat waves, floods and droughts, but also through several diseases which are sensitive to changes in temperature and precipitation. These include common vector-borne diseases such as malaria and dengue fever, but also other diseases like malnutrition and diarrhoeal illnesses (WHO, 2008).

The heat wave which swept through Europe in the summer of 2003 led to the deaths of some 70,000 people in Europe. The inhabitants of hot regions of overseas Europe could be especially affected by rises in temperature. Furthermore, they could also be affected by increases in certain diseases resulting from climate change. The mosquito *Aedes aegypti*, vector of the dengue fever and yellow fever viruses, was recently reported in Madeira (see Box 5.7). Dengue fever in the Caribbean (see Box 2.5), toxic algae in the Reunion Island (see Box 3.2) and ciguatera in French Polynesia (see Box 4.5) are all being closely monitored.

Dislocated cultures and traditions

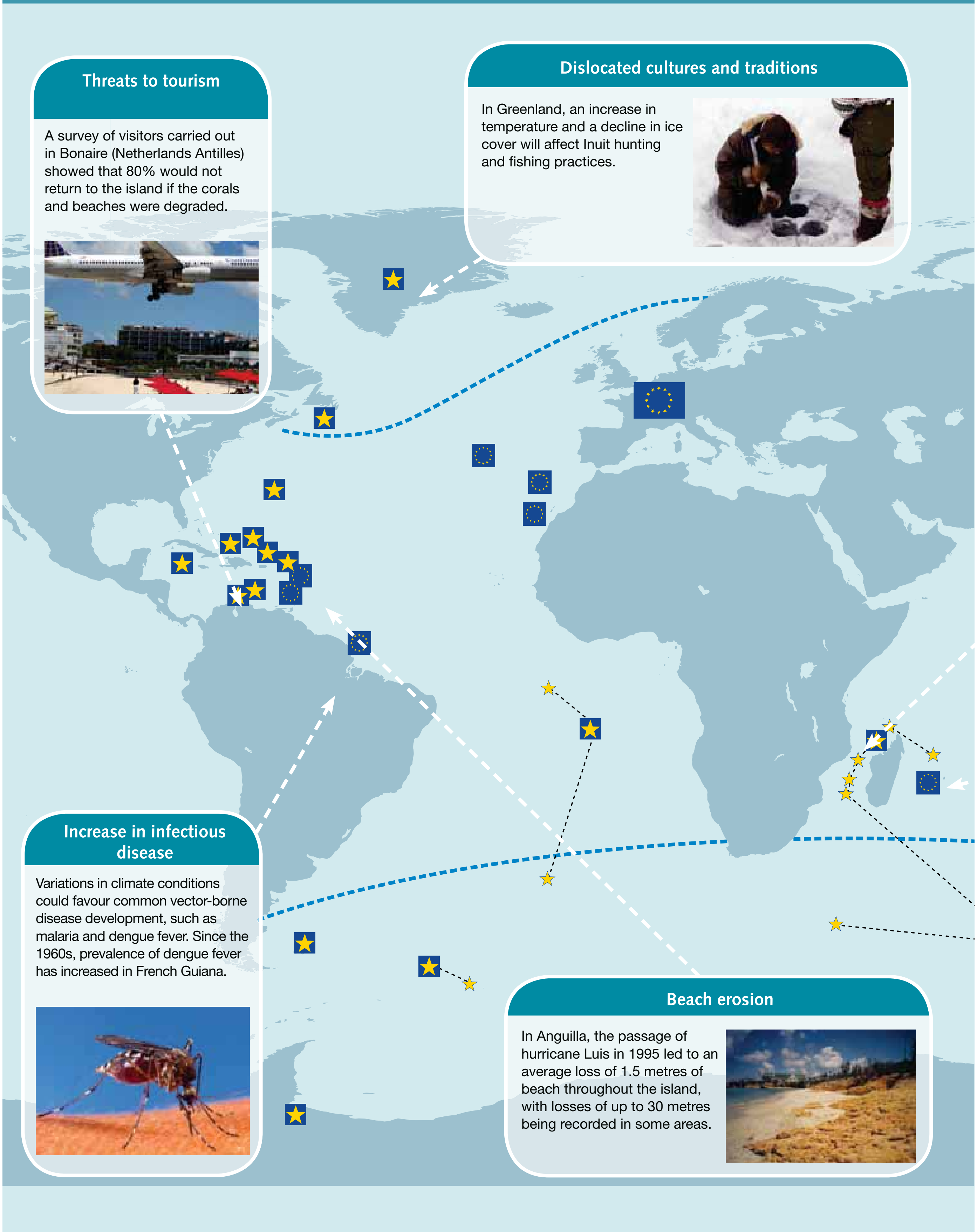
Rural populations in tropical regions are very close to nature, through subsistence agriculture and fishing, but also through traditional medicine, art and spirituality. Degradation of biodiversity threatens the very identity of these islands.

Climate change will also bring about changes in life styles in many traditional societies. Inuit hunting and fishing practices in Greenland will be seriously affected by a decline in the ice cover (see Box 7.3). The inhabitants of the atolls of French Polynesia may one day have to leave their islands, thereby becoming one of the world's first climate refugees (see Box 4.1).

TaranRampersad

Fisherman in French Guiana

Map 5 : Climate Change Socio-Economic Implications in the Overseas Entities of the European Union



Submersion of low-lying atolls

Sea level rise and cyclone intensification could have a major impact on littoral infrastructures. The 84 low-lying atolls in French Polynesia are particularly threatened by submersion.

Repercussions on fishing

Fish stocks could be affected by climate change. In the Indian Ocean, a significant decrease in the abundance of some lagoon fish species was observed after the 1998 massive coral bleaching event.

Toxic algae proliferation

In Reunion Island, bleached corals provide an ideal breeding ground for the development of toxic micro-algae that are poisonous for marine fauna and humans.

Affected agriculture

Rise in temperature, precipitation decrease, soil salinization and proliferation of new pests could severely affect agriculture. Traditional crops on Wallis and Futuna are already impacted by rises in sea level.

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1.6

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2. Caribbean Region

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Introduction

2.1

The Caribbean is home to 115 islands and more than 3,400 islets. They extend over a chain some 4,000 kilometres long and 257 kilometres at its widest point. The region is divided into roughly 25 States and territories with a total surface area of 235,000 km² of emerged land, or an areas approximately the size of the United Kingdom. The islands have a population of about 38 million inhabitants (2002) with a population density of 163 inhabitants per km² (though with large variations among the islands).

The Caribbean includes two outermost regions (OR) of the European Union: Guadeloupe and Martinique. These are French overseas departments. The islands of Saint Barts and the French section of the Island of Saint Martin administratively split from Guadeloupe in 2007 to become separate overseas territories in their own right but have not as yet achieved the status of OCT. They are dealt with in the Guadeloupe section of this report. The Caribbean region also includes eight European overseas countries and territories (OCTs): six British territories (Anguilla, Montserrat, British Virgin Islands, Bermuda, Cayman Islands and the Turks and Caicos Islands), and two Dutch territories (Aruba and the Netherlands Antilles). The Bermuda Islands are a case apart: they are recognised as OCTs by the European Union, but have rejected the Council of Europe's association status.

Over the last 20 years, tourism has become the primary economic activity in the majority of the Caribbean islands. This has given rise to related local industries, such as construction and services. The second most important economic activity has been the development of offshore financial centres offering attractive tax incentives (such as Aruba and the Cayman Islands). Commercial exports from the islands remain limited, although rum, sugar, and bananas occupy an important position on the commercial balance sheet.

Terrestrial biodiversity

The Caribbean islands have been classified as a significant global biodiversity "hotspot". The region has extremely

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Epidendrum mutelianum, is an orchid endemic to Basse-Terre in Guadeloupe and protected since 1989 diverse ecosystems, ranging from high altitude rain forests to cactus savannahs. Most of the Caribbean islands are volcanic, with rich fertile soils and mountainous landscapes. They have a humid climate with warm temperatures and heavy rainfall. These islands are also home to a large number and variety of ecosystems: tropical rain forests, deciduous seasonal forests, mountain forests and Elfin woodland (forests of wind-exposed short knotty trees that grow on the mountain ridges). Other islands, such as Turks and Caicos, are coral islands, made up of successive layers of coral debris. They have flatter landscapes, are more arid and have less lush vegetation, made up mainly of savannah, thorny bushes, succulents and cacti. The Caribbean

Philippe Feldmann

The Kahouanne Anolis *(Anolis kahouannensis)*, is a lezard endemic to Guadeloupe

is home to a great variety of species, including 13,000 species of vascular plants (6,500 of which are single-island endemic), 600 species of birds (27% of which are endemic), 500 species of reptiles (94% of which are endemic) and 170 species of amphibians (all endemic) (EOE 2008).

Marine biodiversity

The marine biodiversity of the Caribbean islands is just as rich as its terrestrial heritage. The region contains 26,000 km² of coral reefs, which alone represent more than 10% of the

JD Pavkovich

Well preserved corals in Cayman island

world's shallow reefs (Burke, 2004). According to a recent survey by the World Resources Institute, the net economic value accruing from coral reefs through tourism, fishing and the protection of the shores amounts to some US$ 350 to 870 million per year (WRI, 2004). The Caribbean islands are also home to one-third of the world's mangroves, which grow along 25% of their coastlines (Littler, 1989). These ecosystems protect the coastlines from extreme weather events and play an important role in the biological cycles of many species of reef fish (see box 2.6). Finally, the region is home to seven species of marine turtles and 30 marine mammals (NOAA, 2007).

Current threats

Many of the Caribbean island ecosystems have been devastated by human activities and in particular by habitat destruction, the introduction of invasive alien species and pollution. The cultivation of sugar, which remains the primary crop in the Caribbean islands, has led to widespread deforestation, especially at low altitudes, throughout the region. Today, the development of agricultural activities poses an important threat to biodiversity, especially through the extension of cocoa, coffee and banana plantations, which are a threat to many as yet intact areas of natural forest. More recently, important population growth in these islands and the intensive development of the tourism industry have hastened the destruction of natural habitats through the construction of roads, hotels, golf courses and other tourist facilities. The area covered by mangroves has also declined by 42% over the last 25 years, and two of the eight species of mangroves once considered vulnerable have even disappeared (CI, 2007).

The situation is no less serious at the marine level. In the 1980s, White band disease practially eliminated the Elkhron coral (*Acropora palmata*) throughout the Caribbean. This species was the primary coral species of the shallow water zone, providing both a forest-like structure rich in biodiversity, and a natural shallow water wave break. Throughout most of the Caribbean, the shallow reefs zones are now nearly devoid of the species, and have been reduced to fields of rubble or bare rock. The consequences for erosion are considerable (Sheppard, personal communication).

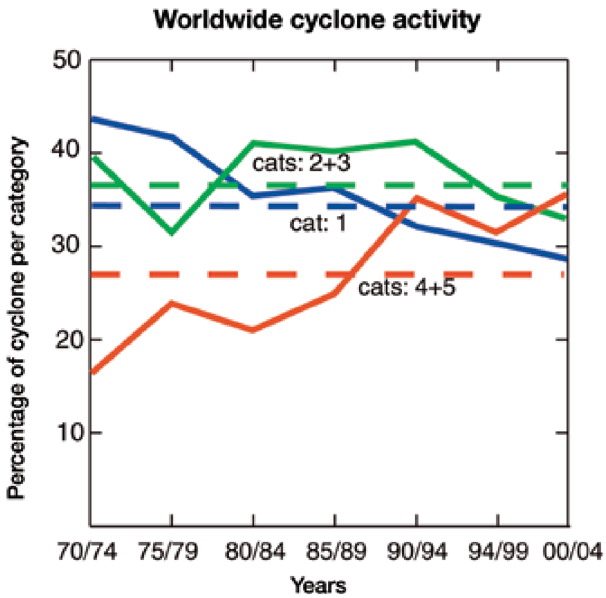
Now, 64% of the remnant reefs are considered under threat from human activities. The greatest pressure comes from over-fishing, which threatens 60% of reefs. In addition, sewage pollution has been identified in 25% of the reefs studied since 1998, partly because only one-quarter of the wastewater discharged from hotels is properly treated (CI, 2007). Some healthy reefs remain in well-managed marine protected areas, such as Bonaire Marine Park in the Netherlands Antilles (see box 2.10).

Climate projections for the region

According to IPCC estimates, mean annual temperatures in the Caribbean region could rise by as much as 2°C between now and 2099 (see Table 4). The trend among the Caribbean islands is slightly lower than the global average. Most climate models also foresee a slight reduction in precipitation levels, estimated at some 12% between now and the end of the 21st century (IPCC 2007).

In addition, extreme weather events could also become more intense in the region. The Caribbean has always been exposed to tropical storms, which sometimes metamorphose into violent hurricanes (called cyclones in the other parts of the world). In an era of global climate change, these hurricanes could become more destructive, with stronger high winds and heavier levels of precipitation. Some studies already indicate that there has been an increase in the incidence of Category 4 and 5 hurricanes in the region over the past 30 years (IPCC, 2007).

Finally, sea levels in the Caribbean islands have risen by an average of 1 millimetre per year over the course of the 20th century. And in the future, the average increases foreseen by the IPCC between now and 2099 range from 0.23 to 0.47 metres (IPCC, 2007). That said, however, some experts believe these estimates to be on the conservative side since they do not take into account rising sea levels caused by terrestrial ice melt.



Percentage of Category 1 cyclone (blue curve), sum of Category 2 and 3 (green curve), sum of category 4 and 5 (red curve) on 5 years period. Dashed lines are averages for- each category from 1970 to 2004 (from Webster et al., 2005)

Table 3: Climate variations between now and the end of the century for the Caribbean region (IPCC, 2007).

Average for 21 global simulation models (scenario A1B). Margin of uncertainty in brackets (25/75% quartiles).

Climate indicator:	Variation between now and the end of the century:
Air temperature	Increase of 2°C [+ 1.8 to + 2.4]
Precipitation	Annual reduction of 12% [- 19 to – 3]
Extreme weather events	Increase in tropical hurricane intensity, with stronger peak winds and heavier precipitation
Sea level	Rise of 0.35 metres [+ 0.23 to + 0.47]

Impacts of climate change on biodiversity

The most visible impact of climate change on the region's biodiversity is coral bleaching. This phenomenon has already affected most of the Caribbean reefs. In 2005, a heat wave caused the bleaching of more than 95% of reefs around some of the islands. The result was a high rate of mortality among corals already weakened by other human impacts (Wilkinson & Souter, 2007) (see box 2.2). The mangroves, which are crucial to the equilibrium of marine ecosystems,

OMMM

Bleached corals in Martinique in 2005

Sarah Sanders

Impacts of Hurricane Ivan on infrastructures in Cayman Islands

could be especially affected by an intensification of hurricanes and a rise in sea levels (see box 2.1). The mountain forests, which are rich in native species, are often the only habitats still relatively untouched by human impacts. They too could be hard hit by climate change because they will be unable to "migrate" higher in the event of temperature increases (see box 2.3). For their part, beaches and other coastal ecosystems could be affected by the increasing violence of the hurricanes and rising sea levels. In addition to these ecosystems, some specific species might also be particularly threatened by predicted environmental changes. Among them are sea turtles, whose populations could decline because of the destruction of their nesting grounds (see box 2.11), and migratory and nesting birds that could be seriously affected by tropical storms (see box 2.13); but also bats, and amphibians like the "mountain chicken" frog in Montserrat (see box 2.23 and 2.24).

Socio-economic implications

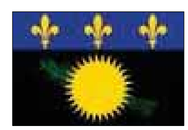
In all likelihood, tourism will be the economic sector most affected by climate change in the region; as a result of the destruction of infrastructure wrought by hurricanes, but also because of the degradation of the beaches and reefs which are the primary attractions of the Caribbean (see box 2.8). The potential reduction in fisheries resources as a result of climate change also poses an important threat for islands like Martinique, Anguilla and Montserrat where fishing remains an important activity. Some studies further suggest that changes in the environment caused by climate change could encourage the spread in the region of disease-bearing insects or parasites which affect humans (see box 2.5).

Responses to climate change

A number of measures have been implemented as part of efforts to adapt to climate change in the region. Some examples are presented in this document. Well-managed marine protected areas can improve the state of reefs and increase their resilience to assaults by the elements (see box 2.10). Monitoring reefs through the voluntary participation of civil society allows changes to be observed, even on those islands where research capacity is limited (see box 2.9). Conservation of some species of coral can be achieved using artificial reefs (see box 2.15); this also helps to limit the impact of hurricanes on coastal areas. The plantation and restoration of mangroves in targeted zones enables the conservation of these habitats which are vital to the overall equilibrium of marine ecosystems (see box 2.16).

Rachel_thecat

Guadeloupe



2.2 Guadeloupe (France) OR

Number of islands:	2 main islands side by side + 11 small scattered islands
Population:	420 000 inhabitants (2006)
Area:	1 628 km²
Population density:	258 inhabitants/km²
GDP/inhabitant:	5 700 €/ inhabitant (2003)
Unemployment rate:	22,7 % (2007)
Economic activities:	Agriculture, food production, tourism

The department of Guadeloupe, situated some 600 kilometres to the east of the Dominican Republic, consists of two large side-by-side islands, Grande-Terre and Basse-Terre, as well as 11 smaller scattered islands, including Marie Galante, the Saintes and Désirade. To the north of the Lesser Antilles, the Island of Saint Barts and the French sector of Saint Martin were also part of this department until February 2007. Since then, they have become overseas communities in their own right. One-third of the area of the two main islands is devoted to agriculture, while the mountainous regions are uninhabitable. Agriculture (mainly sugar cane and bananas), once the economic mainstay of the island, now survives thanks to subsidies. Of the very few industries that exist, most belong to the agro-food sector (sweets, rum distilleries and bottled foods). Currently expanding economic sectors include tourism and the service industries. In June 2007 the rate of unemployment was 22.7%.

2.2.1 Current state of biodiversity

Remarkable habitats and species

Guadeloupe's natural heritage is rich in natural habitats; includes a significant number of native species. There is a wide range of ecosystems distributed according to the exposure of the hillsides, such as high altitude savannahs, tropical rain forests, or dry forests, all of which are home to a tremendous variety of remarkable species. Among them, a native bat, the Guadeloupe Serotine bat (*Eptesicus guadeloupensis*), amphibians, the *Eleutherodactylus barlagnei* frog and the Pinchon frog, as well as many species of orchid. Another remarkable species, the Guadeloupe woodpecker, the only sedentary woodpecker of the Lesser Antilles, is strictly native to the forests of Basse-Terre and Grande-Terre. The nature reserves on the island of Petite Terre are also home to the largest concentration of Iguanas (*Iguana delicatissima*) of the Lesser Antilles, whose population varies from 4,000 to 12,000 individuals (ISG, 2007). The dry forest of Guadeloupe, situated on the coast, less than 300 metres above sea level, is found on the most easily accessible, cultivable and buildable land and is thus highly vulnerable to habitat destruction. Only a few fragments of the original forest remain. The mangroves, and behind them the swampy mangrove forests, cover some 7,000 hectares (Gargominy 2003). Coral reefs are found on all the islands of the archipelago. Some 109 species of fish have been identified on the Grand Cul-de-sac Marin site, three species of marine turtles still lay eggs on the beaches, and 17 species of cetaceans have been identified in Guadeloupe waters (Gargominy, 2003). The protected areas are well developed and include the Guadeloupe National Park, which extends over more than 17,000 hectares, and the Grand Cul-de-Sac Marin reserve, a wetland of global importance (Ramsar site). The Guadeloupe National Park, which has been awarded the European Label for Sustainable Tourism, hosted 550,000 visitors in 2007 (PNG, 2008).

Philippe Feldmann

The Guadeloupe woodpecker (*Melanerpes herminieri*) is strictly restricted to the forests from Basse-Terre and Grande-Terre in Guadeloupe

Current threats

The retreat and degradation of the forest caused by urbanization, cultivation and extractions (hunting and fishing) have seriously impinged upon the biodiversity of Guadeloupe. Charcoal is still locally made at the expense of the dry forest. Forest clearing is still occurring in the area of Grands Fonds (Grande-Terre). While in Marie-Galante, the Saintes and Désirade, the mangroves have all but disappeared. Chlordecone, an organochlorine-based insecticide, once used intensively against weevils in the banana plantations, and outlawed since 1993, has permanently poisoned some of the soils and waters of Guadeloupe (Belpomme, 2007). Efforts have been put in place to ensure access to potable water, but the soils of some regions of the island and other islands in the Antilles have been irretrievably polluted. Studies are currently being undertaken to assess the impacts of these products on health. With a few exceptions, the effluents from the distilleries are little or poorly treated. As for the coral reefs, more than 50% of the reef base has been degraded, due in part to poor management of the pollution arising from sewage and agricultural activity (Reefbase 2007). Many marine grasses have also been damaged by chemical and land-based pollution. A large number of herbivorous fish, such as the parrot fish, have been over-fished and the algae are now gaining on the coral. Some sites, such as the Pigeon Isles are also being overrun by keen deep-sea divers.

Philippe Feldmann

Tropical humid forests in Guadeloupe

Box 2.1: Hurricanes and Mangroves: the Impact of Hugo on the Mangroves of Guadeloupe

These ecosystems of major biological importance are particularly vulnerable to tropical storms and hurricanes. A study conducted by the University of the Antilles and Guyana in Guadeloupe revealed that red mangroves had lost as much as 75% of their surface area (80% of the biomass), due to the widespread death of the species just after the hurricane Hugo (Imbert, 2002). On the other hand, these populations recovered very quickly after this event. Red mangroves account for about 50% of the mangrove coverage in the Caribbean. In the past, degraded zones have taken an average of 10 years to regenerate; while the average time that elapsed between hurricanes in the territory was 25 years during the last century. An increase in the intensity of tropical storms as a result of climate change means that the mangroves will potentially no longer have the time they need to regenerate between two weather events. Furthermore, rising sea levels will compound the direct threat which hurricanes pose to these habitats. These new phenomena are likely to increase the level of degradation, particularly since the mangroves of the Caribbean are already substantially reduced and weakened. They have already been cleared throughout the region to make way for agriculture, tourist infrastructure, ports, airports, etc. Climate change therefore represents a further threat to add to existing pressures on these habitats. In the light of this, it is vital to reinforce all mechanisms aimed at protecting and assisting the regeneration of the mangroves in the region.

Daniel Imbert

Impacts of Hurricane Hugo on red mangroves in Guadeloupe

2.2.2 New threats resulting from climate change

Impacts on terrestrial ecosystems

Situated behind the mangroves, the flood-prone freshwater ecosystems of Guadeloupe seem to be the most vulnerable to climate change. Sandwiched between the mangroves and human settlements, these swampy areas will be unable to expand inland as the salinity of the water increases, and rising sea levels could well result in their disappearance. The mangrove zones are also threatened by rising sea levels and the increase in the intensity of tropical storms (see Box 2.1). At the same time, the summit areas of the mountain forests, which are highly fragmented and specially adapted to prevailing conditions, and where the largest numbers of native species are to be found, will also be affected by changes in temperature and levels of precipitation. It is likely that there will be an upward movement of ecological families whose place will be usurped by more opportunistic species, with the result that specialized adapted species will become increasingly rare or even disappear. This could lead to a deterioration of the biodiversity and the landscapes.

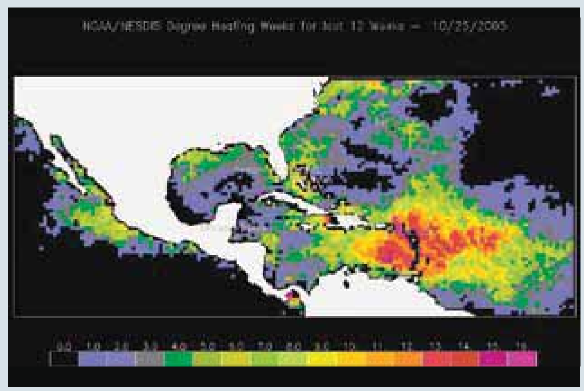
Impacts on marine ecosystems

The corals are already under threat from the impacts of human activities (pollution, over-exploitation of resources, deposits of sediment on the reefs, etc.). Climate change is likely to exacerbate this degradation and reduce the resilience of these ecosystems (capacity to resist and recover). Over the last few years, Guadeloupe has experienced some major episodes of coral bleaching. The most recent (2005) resulted in largely irreversible damage to coral reefs throughout the Caribbean (see Box 2.2). As a result of damage to the coral, numerous other marine species were also affected, such as the reef fish and the herbivores that depend directly upon these habitats for their survival. Furthermore, although no scientific evaluation has as yet been undertaken, severe erosion was observed on a number of beaches as a result of the violence of the hurricanes.

Box 2.2: 2005: White Death of Caribbean Corals

During 2005, the water temperature in the Caribbean basin as a whole exceeded 29°C for six months (from May to November) and was warmest in the east (Sheppard 2005) (see Graphic). That year was the hottest since records began in 1880. These exceptional meteorological conditions led to a massive bleaching of the corals. In Guadeloupe, regular surveys were carried out by a team from the Antilles-Guyana University. They showed that on average 50% of the coral reefs had been bleached in 2005. The resulting mortality was 40% one year later (DYNECAR, 2007). This mortality was observed at sites including the Pigeon Isles, Port Louis and the Grand Cul-de-Sac Marin barrier reef.

The bleaching observed in the Caribbean did not have an equal impact on the corals throughout the islands. Although the beaching was significant in the Greater Antilles (up to 95% in the Cayman Islands), the recorded death rate was minimal in this zone (Wilkinson, 2007). The resilience of the reefs is thus highly variable from one zone to another, with a greater level of mortality observed among weakened reefs that were exposed to high levels of human impacts such as over-fishing, sedimentation and agricultural or domestic pollution. With climate change, hot years like 2005 are likely to become more frequent. The threat hanging over the reefs of the Caribbean is therefore considerable. Even if it is impossible to act on the temperature of the water directly, it is possible to improve the resilience of the corals to these assaults by reducing other human impacts on these ecosystems as much as possible.



NOAA Coral Reef Watch ; Sheppard 2005

Cells are numbers of weeks of temperatures 1ºC above the maximum monthly mean in a zone in 2005. Numbers above four are virtually always accompanied by bleaching, whereas levels above eight are accompanied by widespread bleaching, coral mortality, and long-term reef impacts.

Socio-economic implications

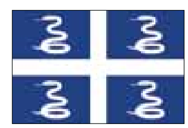
Tourism is the most important and sustainable economic activity in Guadeloupe. The degradation of the corals and the erosion of the beaches could therefore have important consequences for this sector which depends directly on the natural landscape. The frequency of tropical storms and their impact on infrastructure could threaten tourist activities. Similarly, rising sea levels and the submersion of low-lying areas could lead to conflicts over the use of resources (land, water resources). The displacement of structures and populations towards the interior will likely have a strong indirect impact on biodiversity.

Climate change in Guadeloupe could also pose a threat to public health. The rise in temperatures in pond and river water could not only increase the prevalence of bilharzias, an infectious parasitic disease spread by insects, but could also strengthen other existing diseases such as dengue fever, and facilitate the spread of new illnesses.

Finally agriculture and animal husbandry could also be seriously affected by climate change. Variations in temperature and rainfall levels could result in important land-use changes and lead to new interactions between natural and impacted ecosystems. For example, the spread of some diseases or crop-destroying insects could be facilitated, while some self-propagating species could become invasive.

Jean & Nathalie

Martinique



2.3 Martinique (France) OR

Number of islands:	1 island
Population:	397 820 inhabitants (2005)
Area:	1 128 km²
Density:	352 inhabitant / km²
GDP/inhabitant:	14 293 €/inhabitant (2000)
Unemployment rate:	25,2 % (2006)
Economic activities:	Agriculture, tourism, agro-food industry

Martinique is a French overseas department situated some 700 kilometres to the south-east of the Dominican Republic. The landscape of this volcanic island is very rugged; it is made up of a series of massifs that are home to a large number of biotopes. The last active volcano, Mount Pelée, occupies the north of the island and rises to a peak of 1,396 metres. During its 1902 eruption, it claimed 28,000 victims. With a population of 398,000 inhabitants in 2005 and 352 inhabitants per km², Martinique is the second most densely populated French overseas territory after Mayotte. The economy of Martinique is based primarily on agriculture (sugar cane, bananas, and pineapples), tourism and light industry, mainly agro-food industries.

2.3.1 Current state of biodiversity

Remarkable habitats and species

Martinique is the largest of the Lesser Antilles. It is home to a very varied wealth of fauna and flora, complex and original forest ecosystems and remarkable sub-marine landscapes. Overall, the terrestrial ecosystems of this island are relatively degraded. That said, some specific areas are still well conserved. Indeed, 26% of the land area is covered by natural forest which is home to 396 species of indigenous trees (Gargominy, 2003). As for the rest of the Lesser Antilles, Martinique is an oceanic island that was never connected to the mainland. The species which colonized Martinique hailed from two principal sources

(South America and the Greater Antilles) with the result that it is home to an important diversity of species. The island is home to a large number of indigenous species, among them the Martinique Oriole *(Icterus bonana*) and the White-breasted Thrasher (*Ramphocinclus brachyurus*), both very rare and listed as threatened in the IUCN Red List, the dangerous yellow viper (*Bothrops lanceolatus*) with its nasty bite, the Antilles pink toe tarantula (*Avicularia versicolor)* and the Schwartz's Myotis (*Myotis martiniquensis*). The marine biodiversity of Martinique includes 182 species of fish, 48 species of corals, 70 sponges and 331 molluscs. The island has barrier reefs, fringe reefs (of limited length), as well as shallow reef-covered open waters. It also has 10,000 hectares of underwater prairies and 2,200 hectares of mangroves (Gargominy, 2003). In addition to the regional natural park of Martinique, which extends over more than 70,000 hectares, the island also has protected areas (natural sites, nature reserves and biological protected areas) which include all the different representative landscapes of Martinican biodiversity. At the marine level, Martinique is currently the only French overseas territory devoid of marine protected areas. This situation should shortly be remedied with the forthcoming creation of two regional marine protected areas.

Current threats

Martinique's natural landscapes are seriously degraded. Human activities have a detrimental impact on the natural habitats of the island; these compound recurring natural disasters such as intense volcanic activity and repeated tropical storms. Tourism and urban development, closely linked to population growth, have been directly responsible for the destruction of numerous habitats over the last 20 years. Similarly, the medium and low-altitude rainforests have been decimated to make way for intensive crop cultivation.

Over the last few years, some invasive species have become a major threat; among them, the African tuliptree (*Spathodea campanulata*) has become particularly aggressive. Many mangroves, veritable breeding grounds for numerous species of fish, have been filled in. These zones are also affected by pollution from land-based activities. In the Salines Lagoon, worrying concentrations of heavy metals have been observed in the sediments. The bay of Fort-de-France and the bay of Marin, which are highly polluted, are currently undergoing a long term rehabilitation programme. Some resources such as rock lobster, white urchins (*Tripneustes esculentus*) and queen conches (*Strombus gigas*) remain over-exploited. Marine turtle poaching and accidental catch in the fishing nets are also a serious problem.

2.3.2 New threats resulting from climate change

Impacts on terrestrial ecosystems

Hurricane Dean which passed close to Martinique in August 2007 seriously damaged the forests and the mangroves. A study currently being undertaken by the Antilles botanical gardens and the Antilles-Guyana University, in collaboration with the ONF, will shortly report on its full impacts. A potential increase in the intensity of tropical storms and rising sea levels will have an impact on the large, currently intact, mangrove areas of Martinique and also indirectly on the local fauna. Expected temperature variations could also affect the last remaining preserved high altitude forests of the Martinican massifs (see Box 2.3).

Guillaume Ollivier

The Antillean Crested Hummingbird (*Orthorhyncus cristatus*) is endemic to Antilles

Box 2.3: Impact on High Altitude Forests

The high altitude forests are the best-preserved areas on the island. This is due in part to their relative inaccessibility. As a result, they have been far less affected by human activities and invasive alien species than the coastal ecosystems. A team from the Antilles-Guyana University explored the potential changes that could take place as a result of climate change in the high altitude forests of the Lesser Antilles. In Martinique, as in all the "Mountain Islands" of the Antilles, the sheer variety of biotopes offers a veritable laboratory for the study of changes to the vegetation. The climatic conditions of these islands vary greatly from one mountainside to another, and are divided into multiple "bio-climatic micro regions" depending on their orientation and altitude. The frequency and abundance of precipitation are the principal factors which distinguish one bio-climate from another. The geographical division of species, as well as the spatial and temporal layers of vegetation, are largely determined by the rainfall regime. In Martinique, from the coast to the mountain tops, the bio-climatic ranges extends from a dry bio-climate to an extremely humid bio-climate (see graph). This bio-climatic range in turn determines the different layers of vegetation, which range from dry lowland tropical forest to highland tropical rainforest.

Climate change will in all likelihood lead to longer dry seasons and a progressive reduction of precipitation levels in mountain zones. The result will be the "migration" of the dry bio-climate towards higher altitudes and the progressive disappearance of the humid mountain bio-climate. The forest ecosystems could begin to adapt to the dry conditions and the dry lowland forests could begin to migrate towards higher ground leading ultimately to the disappearance of the highland tropical rainforest (Joseph, 2006). The migration of species towards the highlands and the disruption of existing equilibriums run the risk of creating favourable conditions for invasive alien species, which will eventually impoverish these hitherto preserved landscapes and rob them of their tremendous diversity.

Philippe Joseph

Zoning in the forest ecosystems of the Lesser Antilles

Impacts on marine ecosystems

In 2005, the *Observatoire du Milieu Marin Martiniquais* (OMMM) observed a massive bleaching of the coral reefs of Martinique. The percentage of bleached coral reached an average of 70%. The resulting mortality from this period of bleaching was estimated at 13% in 2006 (OMMM, 2005). Under the aegis of the French Coral Reef Initiative (IFRECOR), a qualitative survey of the fish populations was carried out in four locations. This initiative is managed by the OMMM. An increase in hurricane intensity could also have major impacts on the marine biodiversity of the territory. In August 2007, hurricane Dean ravaged certain parts of the southern reef of the island and had an important impact on the coastal forests and beaches where the Hawksbill turtle lays its eggs. The female of this species generally lays her eggs on the very beach where she was born. If a beach disappears, the turtle population also risks disappearing or becoming highly vulnerable. A study of marine turtle populations is being undertaken by the Sepanmar association (*Société pour l'étude, la protection et l'aménagement de la nature en Martinique*). Each year, three beaches are studied for 15 consecutive nights to evaluate the evolution of the turtle population.

Box 2.4: Climate Change and Agriculture in the Caribbean

Powerful hurricanes, which are increasing in number in the region, have a major impact on the agricultural sector. During the passage of hurricane Dean through Martinique and Guadeloupe in 2007, these islands' banana plantations were completely destroyed. The resulting economic losses were evaluated at 115 million Euros (PECE, 2007).

Root vegetables like cassava (*Manihot esculenta*) or sweet potatoes (*Ipomoea batata*) are also a very important component of the Caribbean diet. They are a major source of nutrition for large sectors of the local populations. Models based on climate projections indicate that climate change could also have negative impacts on the production of these crops (Centella, 2001).

The impacts of climate change on agriculture could have very serious consequences for the economies of islands like Martinique, which are highly dependent on the primary sector.


sharkbait

Vegetable market in Fort de France

Socio-economic implications

In August 2007, hurricane Dean, which claimed two victims during its passage through Martinique, caused serious material damage in particular in the agricultural sector (see Box 2.4).

Climate change is considered by those in the field to pose a major threat to the tourism industry, in particular through increased tropical storms and the erosion of biodiversity. Unfortunately, no economic evaluation of this potential damage has as yet been carried out for this region. Research has been carried out in Martinique to assess the potential impact of climate change on public health and the spread of infectious diseases such as dengue fever (see Box 2.5).

A symposium on climate change in the Caribbean, organized by the *Observatoire national sur les effets du réchauffement climatique* (ONERC) in Martinique in December 2006, contributed to raising local awareness of the importance of this major problem.

Box 2.5: Climate Change and Dengue Fever in the Caribbean

Dengue fever is an infectious disease, transmitted by mosquitoes, that is increasing globally. According to the WHO, 2.5 billion people are exposed to it in some 100 tropical and sub-tropical countries (WHO 2002). Dengue fever is believed to kill about 20,000 people in these regions every year, many of them children (ONERC); while some 100 million people are infected.

Under the influence of climate change, the increase in temperatures and the change in humidity could have important repercussions on the vectors of transmission of many infectious diseases, including dengue fever. Diseases carried by vectors of transmission are complicated and involve numerous factors: vectors (mosquitoes in the case of dengue fever), parasites (the dengue virus), hosts (humans) and environmental factors (habitat, rainfall, temperature, humidity, sunlight). A change in environmental factors brought about by climate change could affect the robustness of the carrying (vector) insect (density, survival rate, lifecycle length). It is likely therefore that there will be an increase in the prevalence of dengue in tropical regions and a shift in the spatial distribution of the vectors of transmission from the tropical zones to the temperate zones (Hopp & Foley, 2003).

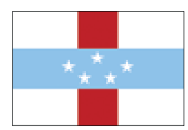
The Caribbean region has seen a marked increase in the incidence of dengue fever over the last 10 years (CAREC, 2007). Research is currently being carried out into the ecology of the transmitting mosquito, the *Aedes aegypti*, and on the prevalence of dengue in Martinique (Etienne, 2006). The effects of the seasons and the sites on the performance of the vector are being studied to better understand the relationship between environmental factors and the prevalence of dengue fever. The first recommendations put forward as a result of this research, and valid for the whole region, point to a necessity to strengthen expertise in the field, the need to strengthen local scientific observations and the importance of organizing an appropriate response in the face of an impending epidemic.

USDA

Mosquito *Aedes aegypti*

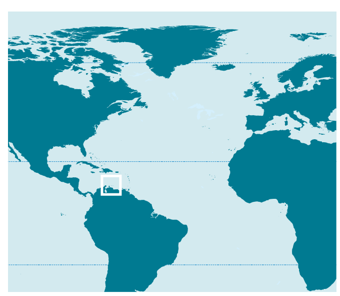
Jessica Bee

Netherlands Antilles



2.4 Netherlands Antilles (Netherlands) OCT

Number of islands:	5 islands and 2 islets
Population:	225 369 inhabitants (2008)
Area:	960 km^2
Populations density:	234 inhabitants / m^2
GDP/inhabitant:	8 379 €/ inhabitant (2008)
Unemployment rate:	17 % (2002)
Economic activities:	Tourism, oil refining, offshore banking



The Netherlands Antilles is made up of five islands situated in the Caribbean Sea. The Windward Islands, to the north of the Lesser Antilles and to the east of Puerto Rico, include the islands of Saba, Saint Eustatius and Sint-Maarten, the Dutch part of Saint Martin (the other part is the French overseas territory formerly part of Guadeloupe). The Leeward Islands, Bonaire, Curaçao and two smaller islands, are off the coast of Venezuela. In December 2008, the Netherlands Antilles will be disbanded to create two autonomous territories of Curaçao and Sint-Maarten, and three Dutch communes with special status, Bonaire, Saba and Saint Eustatius. The Windward Islands are volcanic and characterized by rugged landscapes. The Leeward Islands have a less rugged landscape; they consist mostly of older volcanic formations. The highest point in the Netherlands Antilles (and indeed of the Kingdom of the Netherlands) is Mount Scenery in Saba (862 metres). The Netherlands Antilles has a tropical climate, but the Windward Islands are more humid and subject to tropical storms than the Leeward Islands. In 2008 the territory numbered some 255,369 inhabitants, but the population density is highly variable (ranging from 35 inhabitants per km^2 in Bonaire up to 1,000 inhabitants per km^2 in Sint Maarten). The Netherlands Antilles' economy is based on tourism, with more than a million visitors per year, but also on refining oil from Venezuela (in Curaçao) and offshore financial services. Agriculture and fishing are largely undeveloped.

2.4.1 Current state of biodiversity

Remarkable habitats and species

The Windward Islands, of volcanic origin, are mountainous and lush. They host cloud forests and high altitude tropical rain forests that are home to unique bird species, ancient mahogany trees and rare epiphytes. Saba Bank is a large submerged mountain rising 1,800 metres from the sea-bed, whose flat summit is about 30 meters below the surface of the water. Saba Bank stretches over 2,200 km², making it the third largest atoll in the world and the largest in the Caribbean.

The southern islands are relatively flat and arid, made up of sand dunes that are home to cacti, acacia trees and thorny plants, but also to 13 km² of mangroves and salt marshes. Mangroves are indispensable habitats for the equilibrium of marine ecosystems generally: they provide nurseries for numerous species of reef fish (see Box 2.6). The marshes of Bonaire are home to an important population of pink flamingos. The territory has 250 km² of reefs spread over five islands. The reefs of Curaçao and Bonaire are well conserved because they have not been devastated by successive tropical storms. The Bonaire reef is one of the best-preserved reefs in the entire Caribbean, with more than 340 species of fish observed. The National Marine Park of Bonaire includes the entire coast of the island to a depth of 60 metres. It was established in 1979 and has been actively managed since 1991.

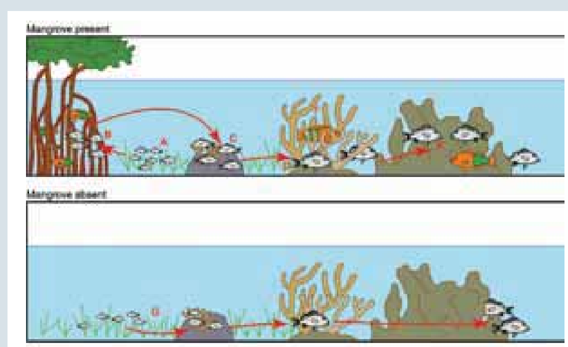
Fernando Simal

Lanscape from the Bonaire Marine National Park with gigantic Cacti and Mesquite bushes

Box 2.6: Mangroves and Seagrasses: Indispensable for Reef Fish

Biologists from the University of Nijmegen have demonstrated conclusively in the Netherlands Antilles that mangroves and seagrasses provide indispensable nurseries for the development of numerous reef fish. Scientists have long hypothesized that mangroves and seagrasses are indispensable to the early development of coral fish, because of the high number of their young found in these environments. To test this hypothesis, nine species of coral fish were studied in mangroves around the Island of Curaçao. An analysis of the contents of the stomachs of the fish studied, as well as chemical analyses, showed that these fish do not venture into the mangroves by chance, but deliberately choose these zones for feeding and protection from predators. Carnivorous fish leave the nurseries when their diets change, before they reach maturity. Herbivorous fish only leave the nurseries once they reach maturity, when they are less vulnerable to predators (Cocheret de la Morinière, 2003).

In the Netherlands Antilles, mangroves have long been destroyed to make way for construction, and the seagrass beds are still regularly polluted. Furthermore, these habitats are now under serious threat from climate change. According to researchers, the managers of marine protected areas in the Caribbean need to shift their focus to ensuring the protection of the entire coastline, and not simply concentrate on protecting the corals. Without the mangroves and seagrass beds, a significant number of economically important common fish species and many species of coral fish would not be able to survive (Mumby, 2004).



Peter Mumby

Impact of the mangrove's absence on coral fishes

Current threats

Two-thirds of the 210 km² of coral reefs around the Islands of Bonaire and Curaçao are under threat from human activities (WRI 2004). The most serious threats are marine pollution, coastal development and over-fishing, especially of conches and rock lobster. The large refinery of Curaçao, which was established in 1916, has also led to significant pollution of the surrounding waters. This infrastructure is outdated and its residual pollution is not properly managed. The recent development and construction of hotels and new luxury housing is also leading to important discharges of untreated sewage waters. The Netherlands Antilles Coral Reef Initiative (NACRI) has reported rapid degradation of the reefs, yet the islands' economies are highly dependent on these fragile marine resources. In 1983, an epidemic seriously affected Curaçao's Long-spined Urchin population, and then spread to the whole of the Caribbean. This had a major impact on the health of the region's reefs (see Box 2.7). On land, large natural areas have been cleared to make way for pasture land, while the island of Sint Maarten has an agricultural history.

Box 2.7: 1983: A Dark Year for the Long-Spined Urchin of the Caribbean

In 1983, just about the entire Caribbean Long-spined urchin (*Diadema antillarum*) population perished in the space of a few months from the effects of a mysterious disease. The contamination began in San Blas in Panama, then spread to Curaçao against the current, but following the route taken by oil tankers. This suggests that the causative agent may have come from the Pacific Ocean, through the Panama Canal. From Curaçao it spread, carried on the currents, to the whole of the Caribbean. The average mortality rate in Curaçao was 98%, less than 10 days after the disease was detected in a given area (Lessios et al., 1984). The urchin population was reduced to no more than 5% of its original number throughout the Caribbean. This epidemic had serious consequences for the shallow coral reefs in the Caribbean. Urchins regulate the numbers of algae that fix themselves on the coral and clean the surfaces where coral larvae can attach themselves. As a result of this outbreak, entire shallow coral reefs disappeared completely from certain areas. Many other factors contribute to the degradation of Caribbean corals, but one thing is certain, the disappearance of Long-spined urchins was a major cause. More than 20 years after the first outbreak, Long-spined urchins appear to be re-establishing themselves slowly and their population has increased in the last few years. The species has in all likelihood developed a resistance to the disease.

Daniel P. B. Smith

Lime urchin (*Diadema antillarum*)

By changing the distribution of certain pathogens, climate change will probably facilitate the spread of diseases like that which decimated the Long-spined urchin population; while ecosystems that are already affected by coral bleaching will be even more vulnerable and will have very low resistance to such assaults in the future.

2.4.2 New threats resulting from climate change

Impacts on biodiversity

Bonaire and Curaçao, both at low altitude, are especially vulnerable to climate change. The predicted rise in sea level will affect the beaches where the marine turtles nest, and the wetlands which are home to the pink flamingos. On the Island of Saba, the impact of rising sea levels on the coastal ecosystems will be more limited because the island has few mangroves and practically no beaches, while the coasts are made up mainly of cliffs. That said, a change in the temperature and levels of precipitation, could result in vegetation like Elfin woodland in Saba or the forests of Curaçao migrating to higher altitudes, the disappearance of mountain top forests (see box 2.3), an increase in the number of invasive species and the impoverishment of terrestrial areas. Unfortunately, there are currently no reliable scientific data surrounding these ecosystems and only one inventory of flora has been undertaken in Saba.

Socio-economic implications

A large area of the town of Willemstad in Curaçao, the capital of the Netherlands Antilles, has been built at low altitude. This town, a UNESCO World Heritage site, is a major tourist attraction for the territory. The town is vulnerable to tropical storms and rising sea levels. A study of the impacts of climate change on the tourism industry has been carried out on the Island of Bonaire. The study revealed that an important change in the environmental features of this island could seriously affect its choice as a tourist destination (see Box 2.8). Finally climate change could also seriously impact upon the already scarce freshwater resources of the low-lying islands. The infiltration of salt water into the water table will further limit the availability of fresh water.

Responses to climate change

On Curaçao, volunteers regularly monitor the health of the coral reefs (see Box 2.9). This has allowed them to measure, with a certain degree of accuracy, the impact of climate change on the health of the corals. Knowledge of the impacts is the first step towards adaptation to climate change. At the same time, the sustainable management of ecosystems will be crucial to improve their resilience in the face of repeated stresses. Bonaire National Marine Park is a prime example of effective management of marine resources (see Box 2.10).

Box 2.8: Impacts of Climate Change on Tourist-Dependent Islands

By modifying the essential environmental characteristics of the Caribbean islands, climate change could have very important consequences for the region's tourist economy. A study conducted by the University of East Anglia looked at the importance of environmental features in determining the choice of destination for Caribbean-bound tourists. A standard survey was carried out among 116 tourists visiting the Island of Bonaire. The results revealed that warm temperatures, clear waters and low health risks were the three major environmental considerations that influenced the choice of destination among tourists. At the same time, the tourists also placed emphasis on the conditions for marine exploration (including the abundance and diversity of the fish and coral life) and other environmental features of the island. The desire of these tourists to return to the island was also strongly linked to the general health of the natural environment. More than 80% of the tourists asked said they would not return to Bonaire – even if prices remained the same – if the corals were seriously affected by bleaching or if the beaches

Todd Neville

Saint-Martin's airport

were highly eroded by rising sea levels. Thus, climate change could seriously affect the tourist economy of the Caribbean, through changes to the natural environment, one of the key determinants of the choice of holiday destination (Uyarra et al., 2005).

Box 2.9: Voluntary Monitoring of Reefs: Reef Care Curaçao

Reef Care is a voluntary organization that coordinates and supports research and monitoring of the state of the reefs in Curaçao. In 1993, a group of volunteers led by a marine biologist undertook to study the exact timing of the yearly mass coral spawning event in Curaçao and determine the coral species participating in it, something that until that time was not well known for the Caribbean region. The result of the first part of the study was to unleash a highly active voluntary movement to monitor the corals in Curaçao. More than 100 volunteers a year undertook night dives over a period of six days and recorded which corals spawned and at what times. The volunteers subsequently undertook a study to measure the abundance and distribution of *Trididemnum solidum*, a colonial tunicate whose population appeared to have exploded and which was suspected of killing corals and overwhelming them. Other studies undertaken by Reef Care Curaçao, for example, measured the impact of tropical storms Bret (1994) and Lenny (1999) and the extent of the bleaching in 1995. In 1996 a long term volunteer coral reef monitoring programme started that is still ongoing today and which feeds data into Reef Check and the GCRMN. Reef Care Curaçao was also involved in monitoring and protecting turtle egg-laying sites and plays an important role in educating the local population, through, among others, a local diving school which introduces 100 children from deprived backgrounds to the beauty of

Paul Hoetjes

Reefcare Curaçao's volunteers monitoring coral bleaching

the reefs every year by teaching them to snorkel. Finally, the NGO also organizes Underwater Clean-up Days once a year with the assistance of numerous local sponsors. Regular long-term monitoring of the reefs is becoming ever more important given the rapid deterioration of this natural heritage. The voluntary involvement of local communities is a very effective way of raising awareness among local communities of the problem on the one hand, and on the other hand, of observing changes in the field where institutional research capacity is weak.

Box 2.10: Bonaire National Marine Park: A Model for Sustainable Reef Management

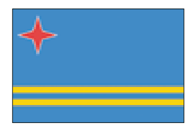
The waters around the Island of Bonaire, home to marine ecosystems of exceptional richness, were declared a Marine Park as early as 1979. This protected area rapidly became an example of good practice in the management of coral reefs. The park includes an oceanic reserve, more than 90 dedicated "SCUBA" diving sites, the equipment necessary for deep sea fishing, and more than 40 mooring buoys along the coast. It is forbidden to drop anchor anywhere in the park. SCUBA Divers pay an annual admission fee of US$ 25 and non divers pay US$ 10. This fee covers the running costs of the foundation itself as well as of both the terrestrial and the marine national parks. These taxes bring in approximately US$ 30 million for the island's economy. The park is managed by a local foundation, STINAPA Bonaire, which is responsible for managing the mooring sites, the educational and research activities, long-term monitoring, and ensuring that a whole host of rules and regulations are respected. Proper conservation of the reefs like the

Paul Hoetjes

one undertaken in Bonaire can help reduce the impacts of climate change on these ecosystems.

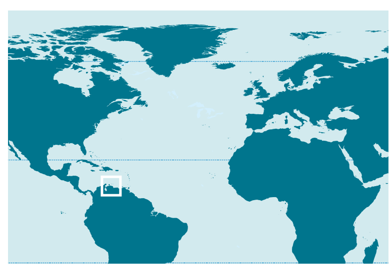
Magalie l'Abbé

Aruba



2.5 Aruba (Netherlands) OCT

Number of islands:	1 island
Population:	101 541 inhabitants (2008)
Area:	193 km²
Populations density:	533 inhabitants / km²
GDP/inhabitant:	14 900 €/ inhabitants
Unemployment rate:	6,9 % (2005)
Economic activities:	Tourism, offshore services, refining



Aruba is a Caribbean island situated 30 kilometres off the coast of north Venezuela. It broke away from the Netherlands Antilles in 1986 to become an autonomous territory of the Kingdom of the Netherlands. The island is relatively flat, with the exception of a central hilly area whose highest point, Mount Yamanota, reaches 188 metres above sea level. The population has doubled since the 1960s, following immigration from South America and the Caribbean, to reach 101,541 inhabitants in 2008. With a GDP of about 14,900 per inhabitant, Aruba is one of the wealthiest territories in the Caribbean. Tourism is the main driver of the island's economy. In 2001, it accounted for 35% of employment and 38% of GDP, with 1.5 million visitors (75% of whom were from the United States). Offshore financial services and oil refining are also major economic activities.

2.5.1 Current state of biodiversity

With its rugged rocks, caves and caverns sculpted by the wind, Aruba has some remarkable geological features. The island is particularly dry and windy and only has a fraction of the tropical flora found throughout the rest of the Caribbean. The vegetation is primarily made up of succulents, a large variety of cacti, as well as some 50 species of bushy trees that have been bent and twisted by the wind. The vegetation is particularly adapted to the dry arid conditions on the island. However, 15% of Aruba is covered by wetlands situated close to the north coast of the island. Arikok National Park, established in 2003, covers a large variety of terrestrial terrains over a stretch of 34 km², including the highest cliffs on the island. Approximately 100,000 people visit every year. Aruba is host to 21 species of nesting birds, including the small native burrowing owl (*Athene cunicu-laria arubensis*), 12 species of reptiles, three of which are threatened (including the blue

Box 2.11: Marine Turtles Under Threat: Monitoring in Aruba

The island of Aruba is home to a large variety of endangered marine turtles. Each year, from March to August, the Hawksbill, Green, Loggerhead and the largest of all marine turtles, the Leatherback turtle, travel thousands of kilometres to lay their eggs on the island's beaches. After a two-month incubation period, the young turtles hatch and make their way instinctively to the sea. They are very vulnerable to predators and only one in a thousand will reach sexual maturity (which can take up to 30 years). These turtles generally return to the beaches of their birth to lay their eggs, they use the earth's magnetic field to find their way back during the long sea journey. The principle egg-laying sites in Aruba are Eagle Beach, Palm Beach and Andicuri. Volunteers from the Turtle Watch Association monitor the populations of Leatherback turtle. The beaches are patrolled at dawn to search for tracks of the species and potential nesting grounds.


Jennie Mallela

Volunteers studying a Leatherback Turtle (Dermochelys coriacea) laying eggs on a beach

The intensification of tropical storms, rising sea levels and the degradation of the reefs driven by climate change, will in all likelihood result in significant erosion of Aruba's beaches, upon which these turtles depend for their livelihoods. A recent study showed that a sea level rise of 0.5 metres would result in the loss of about one-third of the beaches of the Caribbean, and with them numerous nesting grounds (Fish, 2005). Thus, climate change represents a major threat to the turtles of Aruba, and comes to compound the traditional threats which these species face, including: poaching, light pollution on the beach fronts which disorients the turtles, and the degradation and over-use of nesting sites.

Cnemidiphonus arubensis lizard and the Aruba rattlesnake *Crotalis unicolor*), and finally, 176 species of common fish. Aruba is famous the world over for its white sandy beaches, found mainly on the south of the island. Its reefs are relatively small and far less developed than those of Bonaire and Curaçao, because the island is situated on a continental plate. Aruba is home to a particularly rich population of marine turtles, of which four species lay their eggs on the island's beaches. There is no marine protected area in Aruba.

2.5.2 New threats resulting from climate change

Impacts on biodiversity

The threats which climate change poses to Aruba have not been widely studied. However, the island is generally at a low altitude and therefore particularly vulnerable to rising sea levels. The beaches and coastline on the south-west of the island are threatened. These remarkable habitats provide nesting grounds for turtles (see Box 2.11). The coral reefs on the north coast of the island will almost certainly be affected by rising water temperatures and the increase in the intensity and number of tropical storms, which could indirectly reduce the protection of the island. Until now, Aruba was just outside the official hurricane belt. However, the island was recently affected by hurricanes Lenny in 1999, Ivan in 2004 and Felix in 2007. The damage observed was very minor, but could become more serious in the future. Indeed, the ecosystems are not braced for such assaults.

Socio-economic implications

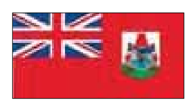
Aruba is a low-lying island with a heavily populated coastline. It is therefore particularly vulnerable to rising sea levels. Furthermore, the tourism sector is directly threatened by the potential degradation of the beaches. The fisheries sector in Aruba is minor; therefore the potential threat to this sector from climate change will not have a major influence on the economy of the island.


Gina Sanfilippo

The Aruba Island Rattlesnake (*Crotalis unicolor*) is a threatened endemic species

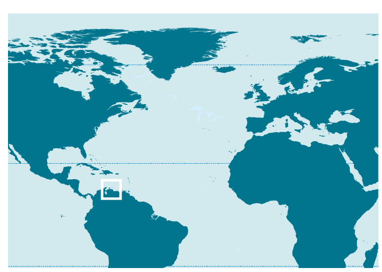
Mike Pienkowski

Bermuda



2.6 The Bermuda Islands (United Kingdom) OCT

Number of islands:	8 main islands and more than 130 coral island
Population:	65 773 inhabitants (2008)
Area:	53.3 km²
Population density:	1 241 inhabitants / km²
GDP/inhabitant:	44 000 €/ inhabitants (2004)
Unemployment rate:	2,1 % (2004)
Economic activities:	Financial services, tourism industry



The Bermuda Islands are a British Overseas Territory situated in the North Atlantic, some 965 kilometres to the east of the North Carolina coast. Bermuda is an OCT because it is placed on Annex II of the European Commission Treaty, but does not fall under the scope of the OCT Decisions that the European Council takes every 10 years, at its own request. The territory is therefore not subject to the Overseas Association Decision. The sub-tropical climate of Bermude is warmed by the Gulf Stream whose heat and humidity are transmitted by the westerly winds. The summers are relatively warm rising to 30°C while the winters are mild with an average low of 18.5°C. Atlantic storms and cold fronts can send the temperatures plummeting; however, these rarely fall below 10°C. One defining feature of the Bermuda Islands is their very limited freshwater resources because of the complete absence of rivers or lakes in the archipelago; although ground water extraction is conducted, rainfall collected from roofs provides the main source of fresh water. With a GDP per inhabitant of an average of 44,000 Euros (2004), the Bermuda archipelago is the wealthiest overseas entity of the European Union. With a population density of 1 241 inhabitats per km², it is also, by far, the densest entity. The economy of the territory is based primarily on financial services, particularly re-insurance for which Bermuda is a leading centre, and the tourist industry.

2.6.1 Current state of biodiversity

Terrestrial biodiversity

The terrestrial biodiversity of the Bermuda Islands is fairly rich with a significant number of endemic species. However, a number of endemic and native species have already been driven to extinction and several other species are now severely threatened and in danger of extinction. When the first settlers arrived in the 17th century, the terrestrial vegetation was dominated by dense forests of Bermuda cedar (*Juniperus bermudiana*) interspersed with Bermuda palmetto (*Sabal bermudana*) and Olivewood (*Cassine laneana*) all of which are endemic trees, and about 150 native plants (Glasspool, personal communication). The cedar forests were exploited for boat building. Later, they came under pressure from coccids, most notably the juniper scale (*Carulaspis minima*) and the Oystershell scale (*Insulaspis pallida*), which were introduced in the 1940s (more than 8 million specimens were destroyed). While these endemic trees are now widely planted, these forests have largely given way to lawns and golf courses and today cover no more than 10% of their original surface area. The endemic vegetation of the Bermuda Islands also includes eleven species of flowering plants, three species of fern, two species of moss, ten species of lichens and 40 species of mushrooms (Ward, personal communication). The Bermuda Islands' relative isolation from the North American continent precluded their natural colonization by mammals (with the exception of bats), amphibians and most reptiles. The arrival of settlers in the archipelago and the introduction of alien species (plants, mammals, reptiles, birds, etc.) rapidly modified the terrestrial biodiversity; today, or more than 1,600 resident plant and animal species, only 27% are native (Glasspool, personal communication). That said, there nonetheless remains an important indigenous insect population made up of more than 1,100 species, 41 of which are endemic.

D. Wingate

The Bermuda cedars *(Juniperus bermudiana)* were destroyed by several introduced scale species

Marine biodiversity

The waters surrounding the Bermuda Islands are warmed by the Gulf Stream which delivers the larvae of a wide variety of Caribbean marine species and allows their survival at this high latitude. The marine fauna and flora is largely derived from and closely resembles that of the Caribbean; it represents what can be described as the northernmost outpost of the Caribbean coral reef ecosystem. The Bermuda platform forms approximately 1,000 km2 of shallow marine habitats on the flattened top of an extinct volcano. A variety of marine habitats are represented on Bermuda. Coral reefs ring the platform creating an atoll-like lagoon which supports seagrass meadows, soft bottom communities and limited mangrove forests.

Bermuda has extensive cave systems which have largely been drowned by sea level rises following the ice ages. These caves are home to a very large proportion of Bermuda's endemic biodiversity. Of 86 species identified from Bermuda caves, 80 are endemic, including two new orders of crustaceans, one new family and 15 new genera (Ward, personal communication). Some 25 of these species are listed as critically endangered due to their isolated and limited range coupled with the threats posed by the dense human population and development pressures on the land above the caves (IUCN Red List).

C. Lascu.

Marine caves in Bermuda shelter many endemic species

Current threats

The main threats to biodiversity are habitat destruction and fragmentation on the one hand, which are the result of property development and invasive alien species on the other hand. More than 50% of the land mass is considered developed with about 15% of the surface concreted. Gardens, golf courses and agriculture occupy a further 20%; no undisturbed upland valleys remain and 75% of upland coastal habitat has been developed. 22 invasive plant species are now a dominant feature of the 30% of Bermuda's land area that remains undeveloped (Glasspool, personal communication). Seepage from septic systems and quarrying activities have caused environmental degradation and destruction of some of these caves.

2.6.2 New threats resulting from climate change

IPCC climate projections for the "North East America" zone, which includes the Bermuda Islands, indicate a possible increase in temperatures in the region of 3.6°C [+ 2.8°C to + 4.3°C] by 2100. Annual average rates of precipitation could also increase by 7% [+ 5% to+ 10%] (IPCC, 2007). However, these projections are for the whole North East America zone and do not necessarily take into account more localized changes or differences between continental areas and island or oceanic environments. A change in precipitation levels may have seriously negative consequences for the specific terrestrial fauna and flora of the archipelago.

Impacts of climate change on terrestrial ecosystems

Rising sea levels pose a serious threat to coastal areas in the Bermuda Islands. Increasing salinity of marshlands is one of the first consequences that has been observed. In Paget Marsh for example, a recent period of extreme high tides lead to the death of several ancient Bermuda Cedars. In another area a low-lying farm plot has been abandoned and turned into a salt marsh due to persistent salt-water intrusion. Rising sea levels combined with hurricane activity have also severely impacted the Hungry Bay mangrove forest, the largest remaining mangrove swamp in Bermuda. Like the Island's coral reefs, Bermuda's mangroves are significant for being among the northernmost stands in the world. Recently coastal erosion has been accelerated by intense hurricane activity. This has been compounded by the effects of these storms on the invasive Whistling Pine (*Casuarina equisetifolia*). This fast growing, shallow rooted tree invades coastal areas where it tends to topple in hurricanes taking pieces of the soft limestone with it. Increasing storm activity has also severely impacted the nesting burrows of the endemic Cahow (*Pterodroma cahow*) and the White-tailed Tropicbird (*Phaethon lepturus catesbyi*). Bermuda represents the largest single nesting population of this species of Tropicbird (Glasspool, personal communication).

Impacts of climate change on marine ecosystems

Several bleaching episodes have affected the Bermuda Islands' coral reefs (including in 1991, 1994 and 1996, all years in which recorded temperatures were above average), however, mortality rates remained low thanks to the good health enjoyed by the corals in this region coupled with the relatively short duration of these thermal assaults on Bermuda's reefs. The greatest challenge for Bermudas' corals is likely to result from the degradation of corals throughout the rest of the Caribbean region. Indeed, corals from the southern areas of the Caribbean region are responsible for supplying a significant portion of coral larvae to Bermuda. The observed decline in Caribbean coral reefs (they have lost up to 40% of their surface area) is serving to further isolate the Bermuda reefs. The geographical isolation of these reefs, which is accompanied by a more limited genetic diversity, limits the capacity of the reefs to adapt to environmental changes (Jones, 2004).

Box 2.12: Nonsuch Island: Native Trees More Resistant to Hurricanes

The restoration of Nonsuch Island to represent pre-colonial Bermuda has been called the "Living Museum Project" and can probably lay claim to be one of the first island restoration efforts of its kind. Inspired by the "discovery" on adjacent but smaller islands of 7 breeding pairs of the supposedly extinct endemic petrel or Cahow in 1951, this restoration effort has focused on the 5.9 hectare island which lies within Castle Harbour, St. Georges, a World Heritage site. Over the past five decades, thousands of endemic and native plants were transported to the Island, and planted to create native upland forest, upland valley, coastal hillside, mangrove, saltmarsh, beach and dune and fresh and saltwater ponds. By 1990, the new forest comprising the three endemic trees, the Bermuda Cedar, Olivewood Bark and Bermuda Palmetto, as well as several of the other endemic flowering plants and a suite of native species, had progressed to the stage where successful self-propagation of many species had begun (Glasspool, personal communication).

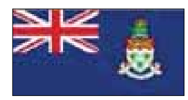
Despite a series of hurricanes since the late 1980's (Emily, Dean, Felix, Gert and Fabian) that toppled vegetation across the rest of the Island, Nonsuch remained largely unscathed with no more that 5% of the natives being damaged during Hurricane Fabian, a Category 3 storm with winds of up to 195 km/hr (Glasspool, personal communication). In contrast, coastal erosion on the rest of Bermuda was exacerbated by the presence of invasive species, most notably the Casuarina (*Casuarina equisetifolia*), which had been planted Island wide as a replacement to the widespread decimation of the cedar tree by an introduced scale insect in the 1940's.

Konrad Glogowski

Natural vegetation in Nonsuch island was particularly resistant to Hurricane activity

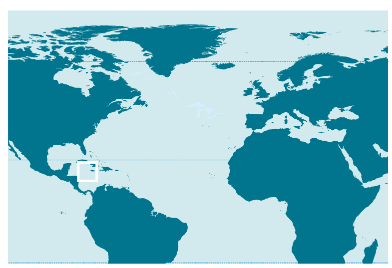
Mike Pienkowski

Cayman Islands



2.7 Cayman Islands (United Kingdom) OCT

Number of islands:	3 islands
Population:	47 862 inhabitants (2008)
Area:	260 km²
Population density:	182 inhabitants / km²
GDP/inhabitant:	19 700 €/ inhabitants (2004)
Unemployment rate:	4,4 % (2004)
Economic activities:	Tourism, offshore financial services



The Cayman Islands, a British territory situated to the south-west of Cuba, are made up of three principal islands: Grand Cayman, Little Cayman and Cayman Brac. The highest point of these low-lying islands, which were formed by an uplifting of marine limestone deposits, is at an altitude of 18 metres. Many developed areas are only one metre above sea level. The most recent estimate of the population of the Cayman Islands was 47,862 inhabitants (2008), and more than 100 different nationalities. The population has doubled in less than 20 years. The tourist industry is in full expansion. With an estimated one million visitors a year, the Cayman Islands have become one of the most popular destinations in the world for deep-sea divers. One of the greatest attractions on Grand Cayman is the world-renowned Seven Mile Beach, which hosts many hotels. The Cayman Islands are also an important offshore banking centre. The GDP per inhabitant (19,700) is the eighth highest in the world.

2.7.1 Current state of biodiversity

Remarkable habitats and species

Native species richness of the Cayman Islands is relatively limited, given that the species and habitats are similar to those of neighbouring Cuba and Jamaica. That said, close to 75% of the reptiles found in Grand Cayman are native (Seidel and Franz, 1994): among them, the endemic blue iguana (*Cyclura lewisi*), the blind snake (*Typhlops sp.*) and the land boa (*Tropidophis caymanensis*). The dominant vegetation consists of dry sub-tropical forests and mangrove swamps. The humid Central Mangrove Wetland (CMW), which stretches over an area of 3,400 hectares, is the only well-preserved mangrove patch on the island of Grand Cayman. However, the island of Little Cayman, on the other hand, still has 40% wetland coverage on publicly-owned land. The reefs and mangroves protect the islands from storms and erosion while the seagrasses act as nurseries for numerous species of fish. There are 226 species of birds in the Cayman Islands, among them 50 species of nesting birds and 170 migratory birds (Cayman Compass). The swamplands of Little Cayman are an important stop-over for many migratory species. The local government department of the environment has established a well-structured network of marine protected areas and is currently in the process of establishing a series of national terrestrial parks. There are 415 plant taxa (species and varieties) thought to be native to the Cayman Islands, including 29 endemics. A recently published Red List has identified 46% of the native flora to be threatened with extinction mostly as a result of habitat loss (Burton, 2008),

Bill d'Agostino

Cayman Blue Iguana *(Cyclura lewisi)*, an endemic species from Cayman

Current threats

High population growth and the rapid expansion of the tourist industry have greatly weakened the ecosystems of these islands. Habitat destruction is the biggest threat to terrestrial biodiversity throughout the territory. Historically, the native forests were exploited for their wood; more recently urban development has resulted in damage to a large section of terrestrial ecosystems and wetland areas of Grand Cayman. Wetlands are still subject to large-scale clearance to make way for tourist developments, particularly along the western peninsula of Grand Cayman. The territory has witnessed many extinctions since the arrival of settlers with, among others, the local disappearance of three bird species, two species of mammal and the freshwater Cuban spotted crocodile Crocodylus rhombifer. Despite sound policies for the designation and regulation of marine protected areas, 80% of the reefs of the Cayman Islands are threatened, mainly by over-fishing (especially for conch and rock lobster) and by abusive use by divers, but also by coastal development (Linton et al., 2002). Invasive alien species settle and develop rapidly, thereby preventing the survival of indigenous species, primarily in protected areas. A report by the Joint Nature Conservation Committee recorded more than 100 exotic alien species of flora and fauna in the Cayman Islands (JNCC 2007).

2.7.2 New threats resulting from climate change

Impacts on terrestrial ecosystems

The Cayman Islands suffered extensive damage as a result of hurricanes Ivan in 2004 and Wilma in 2005. These violent weather events had a major impact on the coastal ecosystems, the beaches and the mangroves; however, no data quantifying the damage exist. The disappearance of the beaches represents a major threat to the turtle populations that nest there. Similarly, some species of terrestrial birds on Grand Cayman were severely affected by hurricane Ivan (see Box 2.13). The potential intensification of extreme weather events poses a serious threat to all these species.

Impacts on marine ecosystems

The Cayman Islands have experienced several large-scale coral bleaching episodes in 1987, 1995, 1998 and 2005. In 2005 the observed bleaching was particularly strong in these islands. It reached more than 95% in places (Spadling et al., 2001). That said, the subsequent mortality rate among the corals was relatively limited. It has been estimated at only 10% around Grand Cayman; while the corals of Little Cayman have practically all regenerated (Reef check). This resilience in the face of extreme events is not common among the reefs of the Caribbean. The Cayman Islands reef also demonstrated its potential to protect the coastal areas of the islands during the passage of hurricane Ivan (see Box 2.14).

Box 2.13: The Impact of Hurricane Ivan on the Cayman Islands Bird Populations

Grand Cayman houses seven sanctuaries for protected birds, including the Queen Elizabeth II Botanical Gardens, Colliers Pond, Salina Reserve, as well as Majestic Reserve. Cayman Brac, for its part, is home to a parrot reserve of more than 70 hectares. Following the passage of hurricane Ivan in 2004, several native birds disappeared from the west of Grand Cayman and the bird population was seriously reduced throughout the islands (Cayman Compass). The bird populations were severely weakened by this extreme weather event, because their food and their shelters were diminished by the violence of the hurricane. Wide-scale, rather than piecemeal, preservation and/or restoration of the native trees and bushes of the Caymans will be necessary in order to create a network of habitats to facilitate the recovery of the bird populations in the Cayman Islands (Cayman Wildlife Connection).

CourtneyPlatt.com

Grand Cayman Parrot (*Amazona leucocephala caymanensis*) eating bitter palm fruits in the absence of food after Hurricane Ivan

Box 2.14: Grand Cayman Barrier Reef: Limiting Hurricane Damage

The damage to the Grand Cayman coastline caused by hurricane Ivan varied greatly between zones, and in particular according to the presence or not of reefs (Young, 2004). There was a strong correlation between levels of coastal erosion and the presence or absence of shallow coastal reefs. Most of the reefs of the southern, eastern and northern coasts of the islands were sufficiently shallow to break the waves and absorb their energy. However, damage to the coast by the heavy swells was extensive in those areas that were not protected by shallow reefs, such as the areas around North West Point, Milford's Bay and High Rock. The west coast, and in particular Seven Mile Beach (the island's main tourist attraction) is relatively unprotected by the reef due to its greater depth. It was nonetheless spared the effects of hurricane Ivan because it did not receive strong onshore winds. That said, future hurricanes could potentially cause much more severe damage to this beach. The intensification of hurricanes due to climate change is a major concern throughout the Caribbean region. The reefs have an uncontested protective role to play and their protection is vital to the very survival of these coral islands.

Impacts of Hurricane Ivan on coasts not protected by the reef in Grand Cayman

Socio-economic implications

In 2004, hurricane Ivan caused damage estimated at twice the GDP of the islands and seriously disrupted the tourist industry (PECE 2006). An increase in the occurrence of violent weather events could completely destroy the economy of these islands. Similarly, the degradation of the corals could also seriously affect the tourist industry. The coral area is a major tourist draw and thus an important source of income.

Responses to climate change

A working group on adaptation to climate change (National Climate Change Adaptation Working Group), led by the Ministry of the environment of the local government, was created in 2007 to develop a strategy for adaptation. Among its first activities was the launch of a programme to restore certain mangrove areas on the island. Similarly, an initiative aimed at restoring the coral reefs using artificial substrates was implemented by one of the hotels on the island (see Box 2.15). Artificial reefs play a very important protective role for the hotel's beaches; while the marine fauna which develops on these reefs serves as an attraction for tourists.

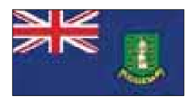
Box 2.15: Artificial Reefs in the Cayman Islands: An Effective Form of Protection?

In 2005, the Reef Ball Foundation, funded by one of the hotels on the island and the Department of the Environment, put together a programme to restore and propagate the corals using artificial reefs. Known as Reef Balls or designed artificial reef modules, they are used to protect a section of the beach against erosion from storm waves. Reef balls, modules made of cement and anchored to the sea bed, enable coral to be transplanted and provide an adapted habitat for reef fish. Some 236 modules were installed on Seven Mile Beach before the passage of hurricane Ivan. Follow-up undertaken in 2006 by the Florida Institute of Technology showed that the artificial reefs survived the passage of hurricane Ivan, while some natural reefs did not have the same resistance. Furthermore, the observations made also showed that the modules had effectively protected the beaches situated further back. Numeric modelling from the Florida Institute of Technology was used to accurately determine the optimal height to be used in future artificial reefs to ensure maximum protection (Reef Ball Foundation). Following the passage of hurricane Ivan, other modules were set up in particularly affected areas. One year later, follow-up activities have shown that the rate of survival of the transplanted corals was very high and the fish populations have significantly increased throughout the area (Barber, communication personnelle). In addition to protecting the beaches against heavy ocean swell, artificial reefs are also a good way to restore damaged reefs. This technology will be important in a climate change context where hurricanes are likely to occur more frequently.

Artificial reef ball a few years after coral implantation

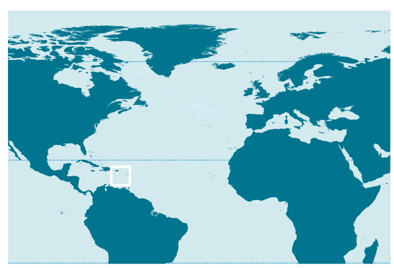

ktylerconk

British Virgin Islands



2.8 British Virgin Islands (United Kingdom) OCT

Number of islands:	60 islands
Population:	24 004 inhabitants (2008)
Area:	153 km²
Population density:	159,6 inhabitants /km²
GDP/inhabitant:	24 200 €/ inhabitants (2004)
Unemployment rate:	3,6 % (1997)
Economic activities:	n/a



The British Virgin Islands, situated 100 kilometres to the east of Puerto Rico, consist of 60 small islands and rocky outcrops making up an area of 150 km² of emerged land, on an underwater plateau of more than 2,000 km², with an average depth of between 20 and 30 metres. Most of the islands are of volcanic origin with a rugged mountainous landscape. Mount Sage on Tortola rises to a peak of 521 metres. The island of Anegada is geologically different from the other islands of the archipelago. It is a flat island made up of limestone and coral. With a population of 24,004 inhabitants in 2008, the British Virgin Islands have seen their population grow by 47% in the last 10 years. The British Virgin Islands have one of the most prosperous economies in the Caribbean, with a GDP per inhabitant of € 24,200 (2004). Offshore financial services are the primary driver of the economy ahead of tourism which, with 350,000 visitors per year (1997), accounts for 45% of the islands' income.

2.8.1 Current state of biodiversity

Remarkable habitats and species

The islands' vegetation is predominantly made up of cacti, thickets and dry forests. There are also rain forests on the upper slopes of the larger islands of Tortola and Virgin Gorda. Floristically part of the Puerto Rican bank, the British Virgin Islands supports approximately 45 plant species endemic to the Puerto Rican bank (Sanders 2006). This includes single-island endemics including the threatened *Acacia anegadensis* and *Metastelma anegadense* (in Anegada) and *Calyptranthes kiaerskovii* (in Virgin Gorda). Other Red Listed species include the *Cordia rupicola* and *Leptocereus quadricostatus* (in Anegada). One quarter of the 24 reptiles and amphibians are endemic. Among them the Anegada rock iguana (Cyclura pinguis) is only found on the Island of Anegada. The archipelago's 380 km² of coral reefs range in size from small fragments of a few square metres to the Anegada reef which is made up of close to 77 km² of coral (Smith, 2000). The archipelago also has 580 hectares of mangroves (of which 75% are found in Anegada), which protect the coasts from erosion and provide nurseries for the young fish, conches, urchins and rock lobsters, among others (Sanders 2006). There are also sea grasses, sandy stretches, and sub-marine hills and vales. The small nesting populations of Leatherback, Hawksbill and Green turtles are in decline. A number of marine protected areas have been designated in the British Virgin Islands, but their management is limited (Spalding, 2001). However, the National Parks Trust is currently establishing a network of marine protected areas which will protect 30% of each type of habitat.

Current threats

The biodiversity of the British Virgin Islands is directly threatened by the rapid development of the tourist industry. In Tortola, the main island, most of the wetlands and mangroves have been degraded. Furthermore, introduced invasive species such as cats, rats, mongooses and wild pigs are placing added pressure on the biodiversity and are particularly affecting those bird species which nest close to the ground. More than 90% of the reefs are under threat or have already been destroyed by human activity (Burke, 2004), especially over-fishing (mainly for conches, rock lobster and commercial fish), as well as coastal development, pollution and land-based sedimentation. Almost all the reefs around the main island of Tortola have already been killed (Sheppard, personal communication).

2.8.2 New threats resulting from climate change

Impacts on biodiversity

The island of Anegada is the most vulnerable to the impacts of climate change because most of its land is low-lying, and therefore at risk from rising sea levels and hurricanes. In Tortola, the main commercial centres on the south of the island are also at sea level and therefore directly threatened. The British Virgin Islands have always been exposed to hurricanes and tropical storms. The most recent, Hugo (1989), Luis and Marylin (1995) were particularly devastating. During the passage of hurricane Hugo, the mangroves showed their capacity to protect the lowlands from the waves. More than 200 boats sought shelter in the Bay of Paraquita when the hurricane passed through. A UNESCO study has been monitoring closely the evolution of the beaches in the Virgin Islands since 1989, immediately prior to the passage of hurricane Hugo which swept some 70 kilometres south of Tortola. The beaches have narrowed by an average of one metre throughout the territory, with up to three metres of beach being lost on the Island of Jost Van Dyke (UNESCO 1996). The 2005 heat wave, which affected the whole of the Caribbean, led to the bleaching of close to 90% of the coral reefs of the British Virgin Islands. The subsequent loss of coral has been estimated at some 35% (Reef Check, 2005).

Socio-economic implications

The tourist industry in the British Virgin Island is without doubt the economic sector most at risk from climate change. The white sandy beaches and the coral reefs, the islands' main attractions, are directly endangered by the growing frequency of tropical storms and successive bleaching events. Flooding of the coastal areas also represents a major threat to the islands' economy. The most important commercial centre in Anegada, for example, is at sea level. Finally, the British Virgin Islands have limited freshwater supplies and infiltration by salt water will only serve to reduce these further.

Responses to climate change

The British Virgin Islands National Parks Trust is responsible for the monitoring and management of the islands' natural resources. In 1996 and 2000, ecological monitoring programmes were implemented at 60 sites with a view to measuring and observing the evolution of several ecosystems or resources (coral reefs, fish populations, sea grasses, water quality, beaches) (ESRI, 2006). These activities are mainly funded by the mooring fees levied from the boats that enter the park (see Box 2.17). The Trust has also implemented a programme to protect the Anegada iguana. A shelter that can house 60 to 90 young iguanas has been built to protect them against predators until they are sufficiently developed to defend themselves. The park undertakes regular monitoring of the turtle populations and their egg-laying sites throughout the archipelago, which are seriously threatened by climate change. A programme to restore the mangroves has been established by the Ministry of Natural Resources of the British Virgin Islands (see box 2.16).

matt.ohara

Beaches from Jost Van Dyke Island lost 3 meters in width on average after the passage of Hurricane Hugo in 1989

Box 2.16: Mangrove Restoration Programme

Around 80% of the mangroves of the British Virgin Islands have been destroyed, largely to make way for tourist development (BVIHCG 2007). A recent development programme on Beef Island has authorized the construction of 663 residences, a 180-acre golf course, and two marinas in one of the largest wetland and mangrove areas of the island – the last remaining sanctuary for a number of migratory birds, some of the most diverse reefs, and an area of major biological importance for numerous species of fish. Climate change, and with it a rise in sea levels and an increase in the number of tropical storms, brings a new threat to the mangroves. Protecting the last remaining mangroves of the British Virgin Islands and restoring degraded areas will be indispensable for the biologically important ecosystems and to protect the islands against rising sea levels.

The local authorities recently acknowledged the importance of these habitats for their ecological and aesthetic value, and their protective role in the face of extreme weather events. The Tortola Department of Conservation has established areas devoted to the replanting of young mangroves shoots in the most severely damaged areas, and continues to monitor the state of these habitats. The annual economic value of mangroves, estimated by the cost of the products and services they provide, has been estimated to be U$200,000 – US$900,000 per hectare (Wells et al., 2006). Costs for restoring both vegetative cover and ecological functions of a mangrove area range from US$225/ha to US$216,000/ha (Lewis, 2005).

www.reefball.org

Red mangrove nursery before restoration

Box 2.17: Preserving and Funding Marine Protected Areas: The Mooring System

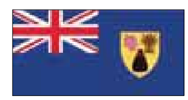
Since 1992, the British Virgin Islands National Parks Trust has established a network of more than 400 mooring buoys (known as the mooring system) throughout the coast, in areas where a high level of boating activity could damage the fragile coral systems or sea grass plantations. The buoys prevent boat anchors and chains from damaging the sea bed. By putting these structures in place, the park hopes to restore the sea beds, which have been severely damaged, and prevent future damage. Overnight mooring, dive mooring, fishing mooring and day mooring buoys have been established, and maps produced to inform leisure and recreational communities of their location. In 2005, an additional anchoring system, the hurricane anchoring system, was put in place to provide added security for boats in the event of tropical storms. Thanks to this system, boat owners are able to protect their boats without entering the mangrove zones in search of shelter. With an increase in the intensity of hurricanes, the mangrove ecosystems are directly threatened by the many chains and lines attached to protect the boats during storms (ESRI, 2006). In addition to protecting the coral reefs and the mangroves, the mooring network is also an extremely effective funding tool for the park's marine conservation programme. In 2002 the income from mooring rights came to more than US$ 200,000 and made the park entirely self-financing (BVI National Parks Trust).

jkahn

Mooring system in Marina Cay

Mike Pienkowski

Turks and Caicos Islands



2.9 Turks and Caicos Islands (United Kingdom) OCT

Number of islands:	8 islands and 40 islets
Population:	22 352 inhabitants (2008)
Area:	430 km²
Population density:	52 inhabitants / km²
GDP/inhabitant:	7 200 €/ inhabitants (2002)
Unemployment rate:	11 % (1997)
Economic activities:	Tourism, fishing, offshore financial services

The Turks and Caicos is an archipelago at the north of the Caribbean, situated 600 kilometres to the south-east of the Bahamas and 250 kilometres north of Haiti. It consists of an atoll of eight coral islands and 40 small islets, the whole extending over a total area of 430 km². The island of Providenciales rises to a high point of 50 metres above sea level. The small permanent population of the islands (22,352 inhabitants in 2008) is inflated by an important influx of tourists (400,000 in 2006). After tourism, offshore financial services and fishing are the main economic activities practised on the island.

2.9.1 Current state of biodiversity

The vegetation of the Turks and Caicos Islands consists of dry forests and mangroves which developed on a limestone base. The archipelago has 26,700 hectares of wetlands (about half of the emerged lands of the archipelago) and 38,000 hectares of inter-tidal sand banks and mudflats (Sanders 2006). The wetlands include open mudflats and periodically flooded mangroves, but also different types of swamp and complex estuaries, which merge with underwater sands. The importance of the wetlands has been internationally acknowledged through the designation of the North Caicos, Middle Caicos and East Caicos as Ramsar sites. The bird life of the archipelago includes 204 species, 58 of which are nesting birds (Sanders 2006). The territory is home to an important number of migratory and nesting birds, many of which are endemic, and particularly wetland birds. The Turks and Caicos are also home to one of the largest populations of Rock Iguana in the Caribbean, with a population of more than 30,000 adults of the Turks and Caicos Iguana (*Cyclura carinata carinata*) monitored (Burton and Bloxam, 2003). The archipelago has the least damaged coral reef in the entire Caribbean region. Its surface area is estimated at some 1,200 km². The north coasts of the four largest islands are fringed by a single reef. Most of the reefs are healthy with a large diversity of corals (more than 30 species). The archipelago has 11 national parks, 11 nature reserves and four designated sanctuaries. These protected areas are managed by the Turks and Caicos National Trust. Although the corals are still very well preserved, 50% of the reefs are under pressure from over-fishing, while pressure tourist activities (water pollution, infrastructure development, anchoring) is on the increase (Reefcheck, 2005).

2.9.2 New threats resulting from climate change

Impacts on biodiversity

The Turks and Caicos Islands are at low altitude and therefore very vulnerable to rising sea levels. Half the emerged land is prone to flooding. The large mangrove areas and sand banks are particularly at risk. These areas are of great biological importance since they provide nurseries for the conches and rock lobsters. They are also an important nesting ground for migratory birds. Many studies have shown that populations of migratory waders from the Caribbean region could be affected by a change in the winds caused by climate change (see Box 2.18). In the marine environment, coral bleaching has been observed on a number of reefs around Providenciales and West Caicos, but the affected areas have not been quantified (Reefbase).

Socio-economic implications

Beach tourism and fishing are important attractions and a significant source of income for the archipelago. These two sectors are directly threatened by the degradation of the coastal areas, the deterioration of the reefs and the effects of changing fish stocks. Furthermore, more than 70% of the archipelago's habitations are situated in the lowland coastal areas and are directly threatened by rising sea levels. Finally, the archipelago has limited freshwater resources; private tanks are largely used to gather rain water. Infiltration by salt water will further compromise the already scarce freshwater resources.

Box 2.18: Storms, Hurricanes and Migratory Birds of the Caribbean

One of the largest communities of migratory birds in the entire Caribbean region is found in the vast and particularly well-preserved wetland areas of the Turks and Caicos. An increase in the intensity of storms could prevent these migratory birds from reaching their laying sites. Long-distance migration pushes the migrotary birds like the Red Knot (*Calidris canutus*) to the limits of their physical endurance. Any change during their migration could therefore have serious consequences for their survival (DEFRA 2005). Storms have a direct impact on the mortality of birds, by exposing them to rain and violent winds. Winds also lead to a geographical displacement of migration, which in turn has an indirect impact on the mortality of these birds by preventing them from reaching their feeding and nesting sites. Increased storm intensity is also likely to affect the productivity of migratory bird species nesting in low-lying coastal areas like the Black-necked Stilt (*Himantopus mexicanus*) or the Wilson's Plover (*Charadrius wilsonia*) in Turks and Caicos (DEFRA 2005). Maintaining the stopover habitats of these migratory birds, such as marshes, mangroves and other wetlands, is extremely important for the preservation of these species which now also face new threats.

Pablo Léautaud

The Black-necked Stilt (*Himantopus mexicanus*) may be threatened by hurricanes' intensification

Responses to climate change

The reefs and fish populations in the archipelago are not monitored, even in the marine protected areas. A conservation fund was recently set up to provide financial support for the sustainable management of these ecosystems. This fund is financed by an annual tax of 1%, to which is added an 8% tax levied on the price of tourist hotels and meals. In addition, an international conference on the Caribbean environment was held in Turks and Caicos in November 2007. Adaptation to climate change in the region figured prominently among the debates (see Box 2.19).

Box 2.19: 2007: Turks and Caicos Year of the Environment

An international conference on the theme "Fostering a Green Culture" took place in the Turks and Caicos Islands in November 2007. It was organized by the local government, in collaboration with the Ocean Conservancy and the National Coral Reef Institute. Members of governments from the Caribbean Community (CARICOM) and British overseas territories, as well as representatives from UNEP, the FAO, the World Bank, several NGOs, universities and scientists from the Caribbean came together to share and exchange knowledge of laws, technological innovations, and research undertaken on the environments in their respective countries. Participants stressed the intrinsic link between environment and development, and underlined that the preservation of nature was an essential part of the economy of the region, for example, through the tourist sector. Also present was Al Gore, Winner of the 2007 Nobel Peace Prize, who stressed the importance of the Caribbean in efforts to combat climate change. As part of efforts to develop and strengthen regional cooperation, the Turks and Caicos Islands stressed the importance of reaching a consensus around environmental issues and proposed that this conference become an annual event for the Caribbean nations.

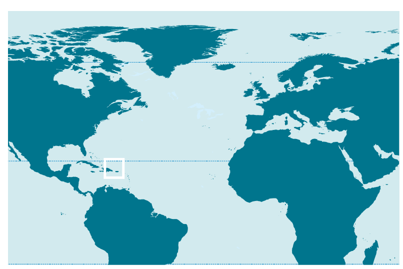
Al Gore in « Fostering a Green Culture » conference

Taco Meeuwsen

Anguilla

2.10 Anguilla (United Kingdom) OCT

Number of islands:	1 main island and 21 uninhabited islets
Population:	14 108 inhabitants (2008)
Area:	102 km²
Population density:	138 inhabitants / km²
GDP/inhabitant:	5 500 €/ inhabitants (2004)
Unemployment rate:	8 % (1997)
Economic activities:	Tourism, fishing



Anguilla is a British territory situated about 260 kilometres east of Puerto Rico. The island is flat and at low altitude; it is 26 kilometres long and 5 kilometres wide. The high point of the island peaks at 65 metres above sea level; the island is made up of limestone and coral. The principle economic activities of the island are tourism, offshore financial services – thanks to a favourable tax regime – and coastal fishing. Some 437 tonnes of fish were captured in 2003.

2.10.1 Current state of biodiversity

Remarkable habitats and species

The island of Anguilla is very rich in biodiversity. It includes 550 species of vascular plants, of which 321 are native, 130 species of birds and 21 species of reptiles (including two lizards found nowhere else in the world: the *Ameiva corvina*, native to Sombrero Island and the *Ameiva corax*, native to Little Scrub Island) (Sanders 2006). On the main island, a number of ponds of great biological importance are fed by the water table. An endemic plant, *Rondelitia anguillensis* (*Anguilla Bush*) is mainly concentrated on the northern and eastern side of the island. Many of the white sandy beaches of Anguilla and its islets are important egg-laying grounds for Hawksbill, Leatherback and Green turtles. The crystal clear waters of the island contain the least damaged coral reefs of the eastern Caribbean. Anguilla has six marine protected areas (Dog Island, Prickly Pear Cays, Little Bay, Shoal Bay, Island Harbour and Sandy Island) but does not have a land-based protected area.

Current threats

The growing development of tourism in Anguilla has seriously damaged the island's terrestrial ecosystems. Observed impacts range from destruction of the dry scrubs to make way for a golf course, to draining of the wetlands, and the filling in of mangroves to make way for the construction of marinas. The reefs of Anguilla are also threatened by over-fishing and coastal development. In recent times, the island has also become vulnerable to quite a number of invasive species. These include, but are not limited to, the Cuban Tree Frog (*Osteopilus septentriionalis*) and the Giant African Snail (*Achatina fulica*), which are causing damage, and are of great concern to the residents of the island. It is believed that both of these species have been introduced by the importation of containers containing exotic plants or other building materials to supply the development of the tourism industry.

2.10.2 New threats resulting from climate change

Impacts on biodiversity

In 1995, hurricane Luis led to the serious erosion of the beaches and sand dunes of Anguilla (see Box 2.20). Serious damage was also observed on the shallow coral reefs (Smith, 1998). The island's corals are similarly threatened by rising water temperatures and coral bleaching. That said, relatively little has been documented about the state of the corals to date. The mangroves were also affected by hurricane Luis, with an estimated mortality of between 68 and 99% depending on the area (Bythell et al., 1996). The deterioration of the reefs and mangroves will probably have major indirect consequences on the fish populations that depend directly upon these habitats for their livelihoods (see Box 2.21).

Socio-economic implications

The principal attraction of Anguilla for tourists rests in the beauty of its white sandy beaches, the quality of its water and the splendour of its reefs. Repeated erosion of the beaches and a degradation of its corals will have a major impact on the tourist industry, the most important economic activity of the territory. The economic consequences of hurricane Lenny in 1999 were estimated at US$ 75 million (PECE), as a result, among others, of the temporary closure of numerous hotels following the destruction of their infrastructure and beaches. Reef fishing is also an important part of the island's economy and a change in fish stocks will almost certainly have a very important impact upon those communities that depend upon the activity.

Mike Pienkowski

Ameiva corvina lizard is endemic to Anguilla

Box 2.20: Hurricane and Beaches: The Case of Luis in Anguilla

Beaches and dunes are sand reservoirs that have formed slowly over the centuries. They provide habitats for many animal and plant species, and in particular, numerous species of marine turtles which come to lay their eggs. The beaches of Anguilla have been monitored by the Department of Fisheries and Marine Resources since 1992. A detailed profile of several beaches around the island is drawn up every three months. It was these observations which allowed the impact of hurricane Luis on the beaches and dunes of the island to be precisely measured. Following the passage of this hurricane in 1995, practically the entire beach of Mead's Bay disappeared. Some 30 metres of dunes were eroded on this beach, compared to an average rate of erosion of 1.5 metres for the whole island (UNESCO 2003). Over the following years, the beach at Mead's Bay reformed but has never regained its pre-hurricane surface area. In order to limit the storm damage to the dunes, UNESCO recommends to island managers that they avoid extracting sand for construction, that they limit the building of infrastructure on the dunes, that they stabilize the dunes with appropriate vegetation and that they undertake regular monitoring of the beaches similar to that undertaken in Anguilla.


Gillian Cambers

Barnes Bay beach before Hurricane Luis in 1995


Gillian Cambers

Barnes Bay beach after Hurricane Luis in 1995

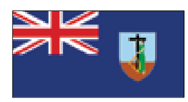
Box 2.21: Threatened Coastal Marine Resources

Most of the coastal marine resources of the Caribbean (reef and estuarine fish, rock lobster, prawns, conches and others) have been over-exploited since the 1980s and are subject to increasing fishing pressure (Bairse, 2004). In addition, these resources are seriously affected by coastal pollution and development. Climate change, through its impacts on coral reefs and mangroves (veritable fish nurseries), will have very grave indirect consequences on these already seriously reduced marine resources. A significant reduction in the density of the fish populations has already been observed on those reefs affected by bleaching (Claro et al., 2007; Jones et al., 2004). Furthermore, with a rise in the water temperature, some studies predict a latitudinal migration of the fish populations towards the north where the waters are cooler (Parmesan and Yoh, 2003). The reef fish, whose migratory capacity is limited, will not be able to move north and run the risk of extinction. Changes in the distribution and abundance of the coastal marine resources will undoubtedly affect island communities like those of Anguilla, whose economy is largely dependent on commercial and subsistence fishing.


Jenny – My travels

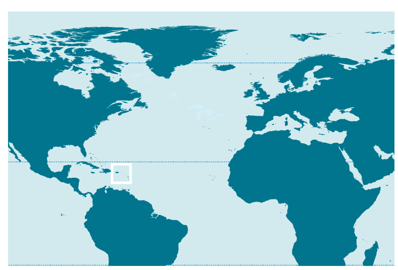
Mike Pienkowski

Montserrat



2.11 Montserrat (United Kingdom) OCT

Number of islands:	1 main island and 2 islets
Population:	9 638 inhabitants (2008)
Area:	102 km²
Population density:	94 inhabitants / km²
GDP/inhabitant:	2 100 €/ inhabitants (2002)
Unemployment rate:	6 % (1998)
Economic activities:	Construction, light industry



The island of Montserrat is a British overseas territory situated 70 kilometres north of Guadeloupe. This small island has been seriously exposed to tropical storms and volcanic activity. In 1989, hurricane Hugo destroyed close to 90% of the island's infrastructure. In July 1995, during the eruption of the Soufrière volcano, Plymouth, the capital of Montserrat, was destroyed and two-thirds of the island's population were forced to leave their homes. The volcano continues to erupt today, but the eruptions are less violent. Before the first eruption in 1995, Montserrat had approximately 13,000 inhabitants; by 2005 this number had dropped to 4,500. Many inhabitants left the island and took refuge in the United Kingdom and Antigua at the time of the eruption. Since 1995, volcanic activity has seriously slowed an already fragile economy. In 1997, a second eruption destroyed the airport and ports, causing serious economic and social upheavals. Since then reconstruction has been the principal economic activity on the island.

2.11.1 Current state of biodiversity

Remarkable habitats and species

The forest cover on the south of the island, around the Soufrière volcano, was almost entirely destroyed by volcanic activity in 1995. In addition, the largest area of intact forest, in the Centre Hills, has been exposed to falling ash and repeated acid rain ever since. Only a small area of mangrove cover in Carrs Bay was not destroyed by the volcano. The Montserrat oriole (*Icterus oberi*), the symbol of the island, was all but decimated by the 1995 volcanic eruption and is now only found in Centre Hills. This species is listed as "critically endangered" in the IUCN Red List and its future in the wild is uncertain. The island is also home to 11 species of terrestrial reptiles (three of them endemic) and 10 species of native bats (Sanders 2006). It is also home to a remarkable giant amphibian, the *Leptodactylus fallax*, known locally as the "Mountain Chicken". It is the second largest species of frog in the world. Today, it is found only on the islands of Montserrat and Dominica, and is also listed as "critically endangered" in the IUCN Red List (see Box 2.22). A recently completed biodiversity assessment confirmed the Centre Hills to be the most important area for biodiversity on Montserrat. The flora comprises approximately 1,000 plant species of which nearly 800 are native and three endemic (*Rondeletia buxifolia*, *Epidendrum montserratense* and *Xylosma serratum*) (Clubbe, personal communication).

Coral reefs are to be found around the island of Montserrat, mainly on the west and north coasts. The island is also a nesting area for Green, Hawksbill and Leatherback turtles. The Centre Hills, although largely in private hands, is a forest reserve but will shortly be designated a Nationa Park following the update of environmental legislation.

Mike Pienkowski

Montserrat Oriole (*Icterus oberi*)

Current threats

Volcanic activity has had a devastating impact on the biodiversity of Montserrat. The eruptions have seriously damaged a number of areas of conservation importance, including the foremost wetland site of the island, the coral reefs and a large proportion of the natural forests. Historically too, Montserrat's biodiversity was also seriously affected by habitat degradation wrought by the early colonial settlers. A large area of the native forest was converted for agriculture and silviculture. Introduced species have also been a major source of pressure on the island's biodiversity, especially rats, which have become predators for the Montserrat oriole and the "mountain chickens". Finally, all the coral reefs of Montserrat are threatened by human activities (Bryant et al., 1998). The most serious threats are over-fishing and sedimentation.

Mike Schinkel

Plymouth, previous capital of Montserrat, was completely destroyed by a volcanic eruption in 1997

2.11.2 New threats resulting from climate change

Impacts on biodiversity

Volcanic activity is by far the most serious threat to the island of Montserrat. Climate change only represents a minor threat when compared to the permanent and potentially devastating effects of the volcano. That said, the forest area in Centre Hills, the only region to be spared from the recent eruption, could be affected by variations in temperature and precipitation. An uphill shift in the vegetation types may severely reduce the area of wet forest and elfin forest, with consequent loss of dependent species. The Montserrat oriole itself is restricted to areas above 200 m, and if forced to shift uphill, the already very limited land area available will reduce further.

An intensification of hurricanes will probably impact upon the beaches of the island, and thus indirectly upon the marine turtles that use them as breeding grounds. In 1989, hurricane Hugo caused major erosion of Montserrat's beaches, but to date no scientific study has quantified this impact. However, a study by the Ministry of Agriculture shows that between 1990 and 1996, under the influence of hurricanes Iris, Luis and Marilyn, six Montserrat beaches were eroded by an average of 21% of their total area, which represents a net loss of 8 metres of beach.

Rising sea levels and the impact of hurricanes will probably also impact upon the island's last remaining fragments of mangrove in Carr's Bay, as well as on the corals of Montserrat. But no study of the state of the reefs has been undertaken. Climate change will also likely have repercussions for the "mountain chicken", one of the island's iconic species (see Box 2.22). Finally, a study of the consequences of hurricane Hugo on the island's bat population concluded that an intensification of extreme weather events will further endanger an already seriously endangered species (see Box 2.23).

Socio-economic implications

The absence of low-lying settlements makes Montserrat less vulnerable to rising sea levels than other Caribbean islands. However, the erosion of the beaches and the

Box 2.22: Amphibians and Climate Change: The "Mountain Chicken" of Montserrat

Amphibians are directly threatened by climate change. Numerous studies point to a strong link between temperature increases and the extinction of several species of frog in South and Central America (Pounds, 2007). The authors of these studies believe that the environmental conditions created by climate change (in particular warmer nights) are ideal for the spread of a fungus, chytridiomycosis, which affects the skins of frogs and spreads a disease, which is fatal for this family. Scientists believe that one-third of amphibians could disappear between now and the end of the century as a result of indirect impacts of climate change (Stuart et al., 2004). The "mountain chicken" of the Caribbean (*Leptodactylus fallax*), one of the largest frogs in the world, is not being spared from this affliction. The populations of Dominica were infected by the fungus in 2002 and their population reduced by 70% in two years (Amphibian Conservation Caribbean). In Montserrat, the populations of "mountain chicken" are still healthy (Garcia, 2005). This island remains one of the last refuges for this species, even though it faces other threats. As its name suggests, it is sought after by the population for its meat, and is also threatened by the destruction of its habitat, the acidification of the surface waters as a result of volcanic activity and the invasive species (rats, cats, pigs, etc.).

Tim Vickers

The Montserrat "Mountain Chicken" (*Leptodactylus fallax*) is one of the biggest frog in the world

growing frequency of tropical storms will only hinder the recovery of the island and weaken the tourist industry further. The likely deterioration of the coral reefs will have an indirect impact on the fish stocks and pose a threat to those families whose subsistence depends on them. It is vital that appropriate measures be taken to ensure the protection of these reefs.

Responses to climate change

Since 2005, the Department of Environment in partnership with the Montserrat Tourist Board, Montserrat National Trust, Royal Botanic Gardens Kew, Durrell Wildlife and RSPB has implemented a Darwin Project to conserve the Centre Hills. This has involved biological and socio-economic assessments to inform the development of a participatory

Box 2.23: Impact of Hurricane Hugo on Bats

Bats are often the only native mammals found on volcanic islands. These species could be affected by an increase in the tropical storms' intensity. A study undertaken in Montserrat allowed the impacts of hurricane Hugo on the island's native bat population to be observed. The abundance and composition of the bat population were measured four years after hurricane Hugo and compared with earlier data. The general abundance of bats on Montserrat was 20 times lower after the hurricane (Pedersen, 1996). The composition of the population was also very different. The small species and fruitivores (e.g., *Artibeus jamaicensis*) had declined considerably, while the number of omnivorous species (e.g., *Brachyphylla cavernarum*) had increased. The insect-eating (e.g., *Molossus molossus*) and fish-eating species (e.g., *Noctilio leporinus*) were largely unaffected. Bat mortality was probably caused by the direct impacts of the hurricane (rain and wind) but also the prolonged absence of fruit and flowers several months after the incident. The increase in the intensity of tropical storms in the Caribbean region is a serious threat to this already endangered family of animals. Bats are key for pollination and the dispersal of seeds in the tropics. As far as feasible, it is indispensable that protective measures be put in place to safeguard these species.

Cressler

The *Artibeus jamaicensis* bat abundance decreased significantly after passage of Hurricane Hugo in 1989 management plan, extensive outreach, increased local capacity for environmental management and the preparation of new environmental legislation to enable the Centre Hills to be designated a National Park. During the project it became evident that a major gap existed in terms of understanding and appreciating the economic value of the Centre Hills. As a result, an economic valuation project was conceived (see Box 2.24). Economic valuation of the environment is a particularly important tool for policy making in the face of a generalized deterioration of the environment, which will only get worse with climate change. In December 2007, the Organization of Eastern Caribbean States (OECS) announced the forthcoming creation of a Centre for Climate Change in the Silver Hills, on the island of Montserrat. This centre, which will bring together scientists and politicians, will seek to enable the development of tools to adapt to climate change; it will draw on experiences from the field. The Centre will work in close collaboration with the entire Caribbean region to study the vulnerability of each island and implement local strategies for adaptation.

Box 2.24: Economic Valuation of the Environment: Montserrat Centre Hills

The Centre Hills, the largest intact forest area remaining on Montserrat, provides a number of important environmental goods and services to the people of the island. An economic valuation study of this forest has been conducted to increase the understanding of the economic importance of further conservation of the area (Van Beukering et al., 2008).

First, a choice experiment was used among the Montserrat population to estimate monetary values for the aesthetic, species conservation, and recreational services provided by the forest. The control of invasive species, which was also included in the experiment, was considered the most important attribute. On average, each household is willing to pay (WTP) US$80 per year for the control of invasive species.

Second, the Total Economic Value (TEV) was calculated showing the relative importance of the ecosystem services from the Centre Hills forest. The tentative estimate of the TEV is around US$1.4 million per year. The most important value, is the tourism value which comprises 32% of the TEV of the Centre Hills. Because the Centre Hills are the only source of drinking water on Montserrat, more than 30% of the TEV of the areas is determined by water services. Species abundance (18%) and forest products for domestic consumption (15%) are also highly valued ecosystem services in Montserrat.

Economic valuation of ecosystems is especially important in a climate change context. It allows the economic losses caused by the potential degradation of a particular environment to be measured precisely along with an accurate estimate of the potential economic gains yielded by adaptation. It is a very important tool for defining a rational adaptation strategy in the face of climate change.

Sarah Sanders

Thousands of visitors enjoy Centre Hills forest each year

Box 2.25: The Global Strategy for Plant Conservation

The Global Strategy for Plant Conservation (GSPC), adopted by the Convention on Biological Diversity, outlines sixteen targets towards halting the current and continuing loss of botanical diversity worldwide (http://www.cbd.int/gspc/). Targets 1 and 2 are foundation requirements necessary for the achievement of the other fourteen targets of the GSPC (Target 1: "a working list of all known plants species"; Target 2: "a preliminary assessment of the conservation status of all known plants species"). A lack of baseline species data and information was identified as a major constraint to achieving both targets, at the Caribbean Regional GSPC Workshop, hosted in Montserrat in 2006 (http://www.kew.org/education/oncourse10.pdf). Despite identification of these two targets as top priorities by all attendant countries, half had not yet achieved one/both, and some considered themselves lacking in expertise or capacity to achieve them.

Andrew McRobb, RGB Kew

Plant species and specimen data collection in Montserrat

With funding from the UK's Overseas Territories Environment Programme (OTEP - http://www.ukotcf.org/otep/index.htm/) the Royal Botanic Gardens, Kew has developed a web-based toolkit which brings together essential country-specific botanical data, including completed Red Lists, key resources for practitioners, and guidelines to producing a Red List. Activities include compiling data from herbarium records, determining species range from publications, preparing a candidate red-list and undertaking targeted fieldwork to provide those data necessary to enable a full assessment to be undertaken and so produce the red list (http://dps.plants.ox.ac.uk/bol/?crlp). The ultimate goal is to provide an on-line searchable database for plant species and their status for all the UK Overseas Territories based on the BRAHMS online database (Botanical Research And Herbarium Management System).

Initially focusing on Caribbean UK Overseas Territories, a Red List for the Cayman Islands is complete, and Bermuda is almost complete. Candidate Red Lists have been completed for Montserrat and the Turks and Caicos Islands, British Virgin Islands, and one for Anguilla started. These data will be maintained on the website and any name changes or changes in red list status updated. Building on the success to-date, it is envisaged that this project will continue to develop and expand to other UK Overseas Territories, and potentially to other Overseas Countries and Territories and Outermost Regions as collaborations are established and data become available.

Rachel the cat

Montserrat Island

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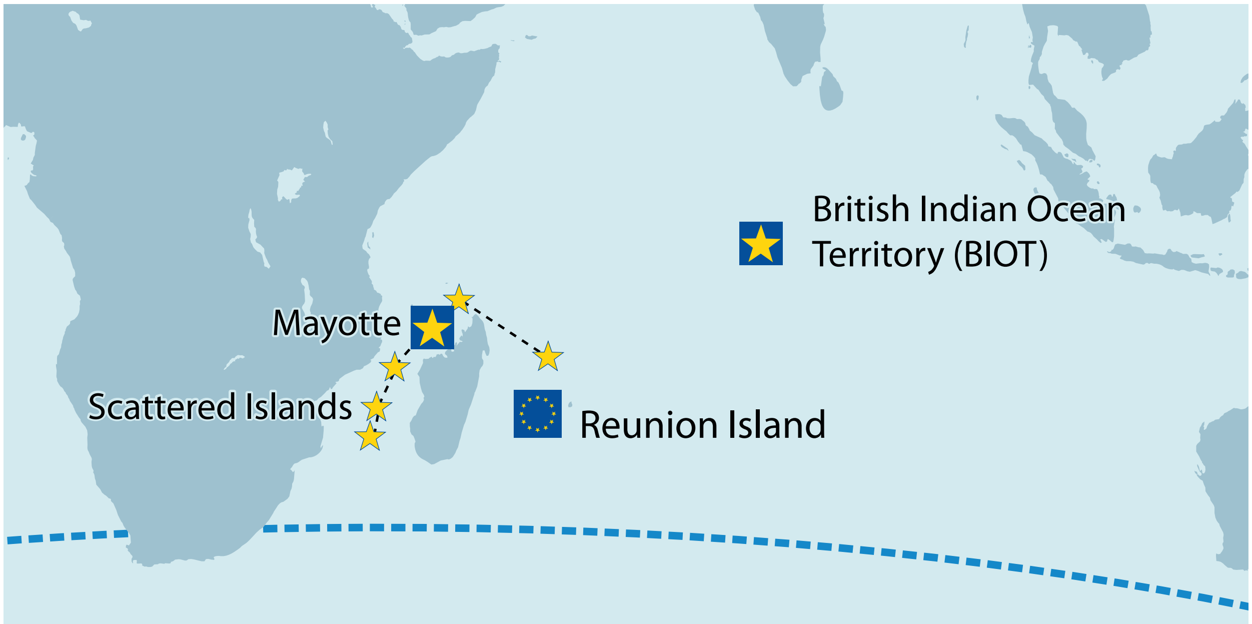
3. Indian Ocean Region

Author: Jérôme Petit (IUCN)

Introduction

3.1



The Indian Ocean is home to four European Union overseas entities. The Reunion Island, situated to the east of Madagascar and close to Mauritius, is both a French overseas department (OD) and an outermost region (OR) of the European Union: it is the only outermost region in the southern hemisphere. Mayotte is an island of the Comoros archipelago to the northwest of Madagascar. This French overseas entity will in all likelihood eventually become a French overseas department (OD), however to date, and under European jurisdiction, its status remains that of a French overseas country and territory (OCT). Situated primarily in the southern Indian Ocean, the French Southern and Antarctic Territories (French acronym TAAF) are also OCTs. With the exception of the French Scattered Islands, around Madagascar, which are dealt with in this chapter, the other French Southern and Antarctic Territories are described in the chapter on the polar and sub-polar regions. Finally, the British Indian Ocean Territory (BIOT), which consists of the Chagos archipelago, is a British territory with European OCT status, situated in the central Indian Ocean to the south-west of India.

The Reunion Island is the most populous French overseas entity, with more than 785,000 inhabitants while Mayotte is the most densely populated with 578 inhabitants per km². The Scattered Islands and the Chagos archipelago have no civilian populations. They are home to a small number of military personnel and meteorologists.

In 2001, the GDP per inhabitant of Mayotte was estimated at 3,960 Euros, some nine times higher than the other Comoros Islands, but three times lower than Reunion. While the tourist sector is growing in Reunion, it remains very small in Mayotte and non-existent in the Scattered Islands and the Chagos archipelago. Mayotte's economy is based on agriculture, subsistence fishing and public sector employment.

Thanks to these ORs and OCTs, Europe has a huge Indian Ocean maritime domain stretching over a total area of about 1.5 million km²; excluding the Southern French Islands.

m. for matthijs

The Dugong (*Dugong dugong*) is a threatened sea mammal found in Mayotte

Managing such a large estate comes with a heavy burden of responsibility, including control of fishing activities, protection of marine mammals and prevention of maritime traffic-related pollution.

Terrestrial biodiversity

Together, the western islands of the Indian Ocean and Madagascar, the fourth largest island in the world, make up one of the 34 globally-recognised biodiversity hotspots as designated by Conservation International. The island

John Turner

The Chagos archipelago contains 55 coral islands scattered in five big atolls

of Madagascar has one of the highest concentrations of endemic species on the planet, with a multitude of endemic genera and families of animal and plant. The neighbouring islands are also home to a tremendously rich biodiversity. They form a chain of relatively recent volcanic high islands, such as the Islands of Reunion and Mayotte; islands formed by the fragmentation of the continental plate, such as the Seychelles; and coral islands and atolls such as the Scattered Islands and the Chagos. The high volcanic islands are characterized by mountain peaks that attract heavy precipitation (up to 6 metres a year on the Reunion Island) and are covered by very dense tropical forests. The coral islands, on the other hand, have dryer climates and less diverse vegetation, however, they are remarkable for their abundant bird life.

Marine biodiversity

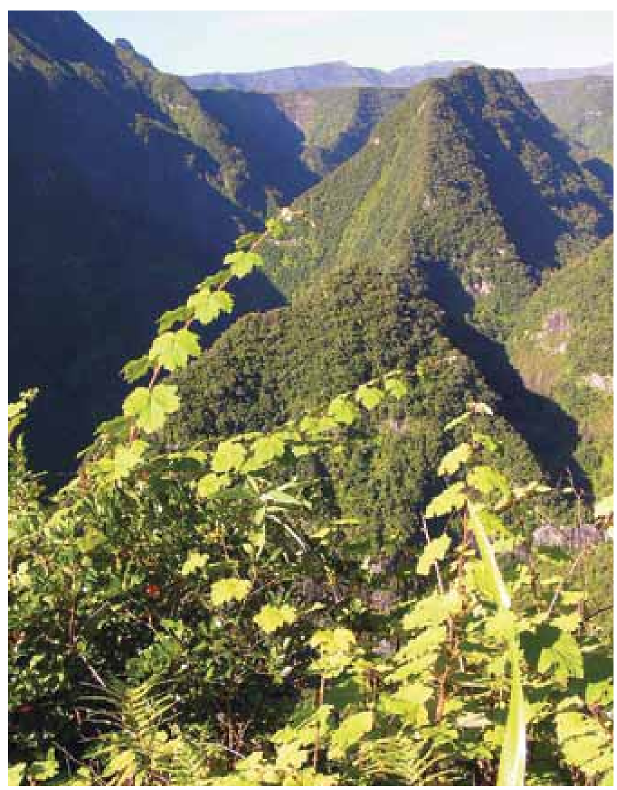
The Indian Ocean is home to about 15% of the world's coral reefs (WRI 2007). Coral formations are relatively limited around the Reunion Island, but Mayotte, the Scattered Islands and the Chagos archipelago have a particularly rich coral diversity. The island of Mayotte has a double barrier reef, a rare phenomenon; while the Great Chagos Bank is the largest atoll in the world. The Indian Ocean is also an important breeding ground for marine turtles. The Island of Europa, one of the Scattered Islands, is one of the most important nesting sites in the world for the Green turtle (*Chelonia mydas*). These territories are also home to a large variety of marine mammals. Among them are numerous species of dolphins, the sperm whale (*Physeter macrocephalus*), the humpback whale (*Megaptera novaeangliae*), Blainville's beaked whale (*Mesoplodon densirostris*), as well as the iconic dugong (*Dugong Dugon*), a rare species listed as "vulnerable" in the IUCN Red List. Mayotte's lagoon alone is visited by 21 species of cetacean, or 26% of global species (Arnaud, personal communication).

Current threats

The direct destruction of the natural habitats is without doubt the biggest threat currently facing terrestrial ecosystems of Mayotte and the Reunion Island. In Mayotte, the primary vegetation has been almost entirely destroyed, with the exception of a few small fragments which cover as little as 3% of the territory (Pascal, 2002). On the Reunion Island, deforestation to make way for sugar cane plantations in the 19th century, and more recently the development of infrastructure and urbanization to cope with demographic growth, have destroyed close to 65% of the natural ecosystems (Gargominy 2003). Despite this, the island has retained more primary forests than most of the oceanic islands on the planet thanks to its rugged landscape; this natural heritage is of global significance.

Alien invasive species also pose a considerable threat to the biodiversity of these islands. On the Reunion Island in particular, the number of invasive plant species is three times greater than the number of indigenous species. Among them, the giant bramble (Rubus alceifolius) has taken on worrying proportions and is spreading over the territory at an alarming rate. Managing these invasive species is probably the biggest and most complex challenge for the protection of the biodiversity of the Reunion Island.

The marine environments of the Indian Ocean have not been spared from the impacts of human activity. Half the coral reefs of the region are degraded (WRI 2007) as a result of over-fishing, domestic and agricultural pollution, and sedimentation caused by land erosion. The remarkable Mayotte Lagoon in particular has witnessed worrying developments with increased sedimentation over more than half of its surface; this is having an impact on the island's seagrass beds and coral reefs. The reefs of the Chagos archipelago have been largely spared from the impacts of human activity and are therefore better preserved.



Damouns

The Invasive Bramble (*Rubus alceifolius*) is an invasive species that spreads rapidly in Réunion Island

Climate projections for the region

According to IPCC estimates, mean annual temperatures in the Indian Ocean could rise by as much as 2.1°C between now and 2100 (Table). Observations made in the Seychelles already point to a significant rise in temperatures between 1961 and 1990 (Easterling et al., 2003). Fluctuations in the El Niño phenomenon (see Introduction) have a direct impact on the surface temperatures of the waters of the Indian Ocean. In 1998, during a major warming episode, the water temperatures throughout the Indian Ocean remained above 29.5°C for several weeks. The impact of climate change on the frequency of the El Niño phenomenon is currently unknown, but it is likely that climate change will significantly increase its extent (i.e., anomalies in water temperature tending towards warmer waters) and impacts (i.e., coral bleaching) over the next few years.

As far as precipitation is concerned, IPCC projections are not as precise as temperature predictions; furthermore, predictions vary across sub-regions and seasons. That said, the IPCC nonetheless predicts a rise in average annual rates of precipitation in the north Indian Ocean, with a rise in precipitation levels in the Seychelles in the summer (December, January, February), and in the Chagos archipelago in winter (June, July, August), and a decrease in the level of precipitation around the Islands of Reunion and Mauritius during the winter months. Torrential rainfalls already significantly increased in the Seychelles between 1961 and 1990 (Easterling, 2003). The IPCC predicts a rise in average annual rates of precipitation of between 3 and 5% for the whole of the Indian Ocean region between now and the end of the century.

There are no reliable data to illustrate the impact of climate change on the incidence of tropical storms in the Indian Ocean. However, at a global level, all predictions seem to indicate that tropical storms will become more violent with stronger winds and more abundant precipitation. This trend will have a direct impact on the western Indian Ocean, which is already one of the most storm-prone regions of the world.

Finally, the IPCC predicts an average rise in global sea levels of 0.35 metres; predictions for the Indian Ocean are similar (Church et al., 2006). It is important to keep in mind that the different models used to predict such rises lead to widely divergent forecasts, which makes such estimates unreliable; furthermore, predicted rises in sea level are not uniform depending on the sub-region. Between 1993 and 2001, a significant rise in the sea level was observed around the Chagos archipelago, while a significant drop was logged around the Reunion Island (Church, 2006).

Table 4: Climate variations between now and the end of the century for the Indian Ocean (IPCC, 2007).

Average for 21 global simulation models (scenario A1B). Margin of uncertainty in brackets (25/75% quartiles).

Climate indicator:	Variation between now and the end of the century:
Température de l'air	Increase of 2.1°C [+ 1,9 to + 2,4]
Précipitations	Annual increase of 4% [+ 3 to + 5]
Evénements extrêmes	Increase in tropical cyclones intensity, with stronger peak winds and heavier precipitation
Niveau de la mer	Average rise of 0.35 metres [0.21 to 0.48]

Impacts of climate change on biodiversity

The most obvious impact of climate change in the region is without doubt coral bleaching. In 1998, the particularly strong heat wave which hit the Indian Ocean caused extremely strong bleaching of the Indian Ocean corals. In some areas more than 95% of corals were bleached (Sheppard, 2003) (see Box 3.7). The average mortality resulting from this episode was estimated at approximately 30% throughout the region, though shallower parts of reefs were more affected than cooler, deeper parts (Sheppard and Obora, 2005). Episodes of bleaching are likely to increase with a sustained rise in temperatures. Some studies predict that the Indian Ocean corals could disappear completely over the next 20 to 50 years as a result of increasingly frequent bleaching events (Sheppard, 2003). Degradation of the corals has a knock-on effect on the entire marine ecosystem. A study undertaken in the Chagos islands showed that the diversity and abundance of reef fish have declined significantly since the 1998 bleaching event (Graham 2007) (see Box 3.8).

stefanottomanski

In 1998, more than 95% of the coral reefs bleached in some zones in Chagos

Rising sea levels and an increase in extreme weather events could lead to erosion of the beaches and coastal ecosystems among the islands of the Indian Ocean. Largely made up of coral, the Scattered Islands and the Chagos Islands are particularly at risk because of their low altitude, while their soils are vulnerable to the sheer power of the ocean swell. Early signs of erosion have already been observed in the Chagos archipelago (see section 3.4). The degradation of the beaches will have important repercussions for the populations of marine turtles which inhabit these islands. These populations will also be under threat from rising temperatures, which modify the conditions in which their eggs incubate (see Box 3.5). Furthermore, Indian Ocean populations of migratory sea mammals will in all likelihood be affected by climate change during their feeding seasons in the Polar Regions (see Box 7.6).

At the terrestrial level, the impacts of climate change on the ecosystems will be more difficult to measure. There are no observation data available for such impacts in the region, but experts consulted have ventured some predictions. On high volcanic islands, such as the Islands of Reunion and Mayotte, a rise in temperatures will probably lead to the upward migration of some species and the disappearance of the high altitude and mountain forests. This restructuring of habitats will likely be detrimental to indigenous species and increase the spread of invasive species that are already exerting considerable pressure on the native habitats of these islands.

Socio-economic implications

Unfortunately, there are not as yet enough data relating to the observed or potential socio-economic implications of climate change on the communities in the region. Only a few hypotheses have been put forward. To start with, the Islands of Reunion and Mayotte have very dense populations in the

Marcel Gréard

The coral bleaching event in 1998 had an impact on the fishing activity in the region

low-lying areas around their coasts. A combination of rising sea levels, the degradation of the natural protection provided by the coral reefs, and an increase in the intensity of tropical storms could have dramatic consequences for the security and way of life of a large number of inhabitants of the coastal zones of the region. In Mayotte, the migration of coastal populations towards the interior would place added pressure on land, which could lead to a number social problems and endanger the last remaining uninhabited natural areas. On the Reunion Island, large coastal urban settlements would be at the mercy of heavy ocean swell if the coral reefs were to disappear. On both islands, degradation of the beaches and coral, risks putting a brake on the development of tourism. The deterioration of the reefs could bring about a decline in the number of commercial species of fish and lead to a drop in the incomes of fishing communities. The economic deficit produced by the 1998 bleaching event was estimated between US$ 608 million and US$ 8,026 million for the entire Indian Ocean (Cesar, 2003). Finally, a rise in the water temperature and the degradation of the coral reefs create ideal conditions for the development of certain micro-algae that are highly toxic for human and marine fauna (see Box 3.2).

Responses to climate change

The Reunion Island has implemented a variety of strategies to adapt to or mitigate the impacts of climate change. This year, 2008, has seen the launch of Reunion 2030, an ambitious greenhouse gas emissions reduction programme whose objective is to make the island a testing ground for renewable energy (see Box 3.3). The Reunion Island is also home to an IUCN French overseas territory-wide initiative on invasive species (see Box 3.1). Similarly, the Net-Biome initiative, an inter-regional research programme funded by the European Commission and coordinated by the Regional Council of the Reunion Island, provides a model for European overseas-wide cooperation, which aims to coordinate research efforts for the protection of ecosystems in the face of global change (see Box 3.4).

In Mayotte, a very interesting initiative has been launched aimed at ensuring long-term monitoring of the beaches and raising awareness of the local population about the fragile nature of ecosystems; this initiative deserves particular attention (see Box 3.6).

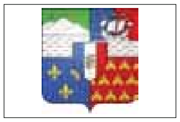
In addition, the Scattered Islands and the Chagos archipelago show interesting potential as a beacon for the scientific monitoring of the effects of climate change on natural ecosystems. Europa in particular, an island almost completely devoid of direct human impacts, is one of those rare locations which could provide scientific data of interest at a regional and even global level. To date, the island's scientific potential has not been sufficiently exploited (see Box 3.9).

John Turner

Many coast erosion examples were observed in Chagos

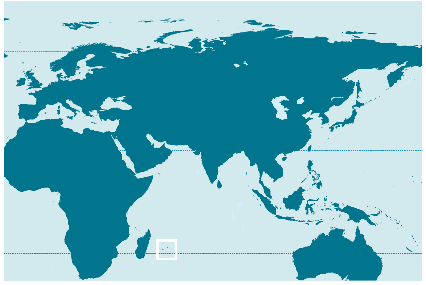
Guy F. Raymond

Reunion Island



3.2 Reunion Island (France) OR

Number of islands:	1 island
Population:	785 000 inhabitants (2006)
Area:	2 512 km^2
Population density:	313 inhabitants / m^2
GDP/inhabitant:	12 000 €/ inhabitants (2000)
Unemployment rate:	30 % (2006)
Economic activities:	Tourism, agro-food industry, agriculture, services



The Reunion Island is a French overseas department (OD) and a European outermost region (OR). It is situated in the Indian Ocean, 700 kilometres to the east of Madagascar. This volcanic island is part of the Mascarenhas archipelago and has a very steep mountainous landscape. It has two volcanoes: the Piton des Neiges, today inactive (3,069 metres) and the Piton de la Fournaise, still regularly active, which occupies the south-east third of the island. The Reunion Island has an area of 2,512 km^2, but its exclusive economic zone (EEZ) extends over an area of 318,300 km^2. With a population growth of 1.8% per year over the last 20 years, the Reunion Island has the fastest rate of demographic growth of all regions of the European Union. For more than a century sugar cane was the island's principal resource, but this has recently been superceded by tourism which is now the primary economic activity. The island welcomed more than 430,000 visitors in 2004. The agro-food sector remains the island's principal industrial activity, in particular sugar cane distilling and rum production.

3.2.1 Current state of biodiversity

Remarkable habitats and species

The Reunion Island's rugged landscape and its extreme climatic variations have resulted in a great diversity of habitats. Depending on the altitude and orientation of the hillsides, there are savannahs, semi-arid forests, swampy thickets, high altitude rainforests and mountain forests in Tamarin. Close to 193 natural environments have been documented (Nomenclature Corine Biotope) and 30% of the total area of the island is still covered by large swathes of native vegetation. These sanctuaries house over 750 species of vascular plants, of which 34% are native, 250 species of mosses, 68 species of terrestrial molluscs, of which 21 are native, and 18 species of native terrestrial birds, seven species of which are endemic (Gargominy, 2003). Since the arrival of humans in 1665, 11 species of birds have already become extinct on the Reunion Island. Some remaining native species are seriously threatened, such as the Mascarene Black Petrel (*Pterodroma aterrima*), listed in the IUCN Red List as in "critical danger of extinction". Furthermore, there are now more than 20 invasive alien species of birds on the island whose impact on the ecosystems is not negligible.

The reef formations around the Reunion Island are not highly developed; nonetheless, they play an important natural protective role in the face of heavy ocean swell and tropical storms, especially in the town of Saint-Pierre. Situated to the west of the island, they form a broken band some 25 kilometres long (or just 8% of the island's perimeter), for a total area of 12 km². The island has no

Parc National des Hauts de la Réunion

Mafate Circus in the Hauts de la Réunion National Park

mangroves and seagrass beds are rare. Three species of marine turtle can be seen on the Reunion Island, the Green turtle (*Chelonia mydas*), the Hawksbill turtle (*Eretmochelys imbricata*) and the Loggerhead turtle (*Caretta caretta*). In the last three years, after a gap of several years, populations of Green turtle have begun returning to nest on the island, in particular on a refurbished beach opposite the Kélonia centre (Ciccione et al., 2007).

The year 2007 was an important one for decisions concerning the protection of Réunion's natural heritage. Two important protected areas were created: the *Parc National des Hauts de La Reunion*, with an area of 1,000 km², covering approximately 42% the surface of the island; and a marine nature reserve, which stretches over 20 to 25 kilometres of reef (PNR 2007). At the same time, France proposed to UNESCO the designation of a central area of "pitons, cirques and ramparts" in the List of World Heritage Sites.

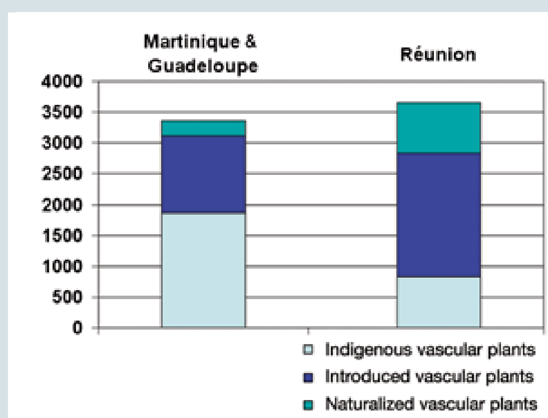
Current threats

The principal threats facing biodiversity on the Reunion Island are direct destruction of natural habitats and the growing number of invasive alien species. Almost all the original low-altitude forests (below 500 metres) have been converted for agricultural or urban development (Gargominy, 2003). The low-altitude semi-arid forest is especially threatened and only a few hectares remain in the west of the island. Invasions of introduced animal and plant species, have hastened the degradation of native habitats. Today there are close to 2,200 introduced plant species on the Reunion Island, of which 700 have become naturalized and about 150 are invasive (Soubeyran, 2008). Since 2005, the French Committee for IUCN has been leading an initiative for invasive alien species throughout French overseas territories; this initiative is coordinated from the Reunion Island (see Box 3.1).

Box 3.1: IUCN Initiative on Overseas Invasive Alien Species

In the past, the foremost causes of biodiversity loss on the islands have been over-exploitation of species and large-scale habitat destruction. Today, these problems have not disappeared; however, they have been superseded by an even bigger threat to island biodiversity: invasive alien species. Alien invasives have become a serious problem in almost all the ORs and OCTs of the European Union. Climate change will exacerbate the problem. It will seriously affect the equilibrium of ecosystems, thereby paving the way for the spread of opportunistic exotic species that could eventually become invasive.

The French Committee for IUCN has begun to implement a French overseas entities-wide initiative on invasive alien species. Launched in July 2005, this initiative is managed from the Reunion Island. The initiative brings together a network of more than 100 experts, supported by 12 local coordinators, whose task is to gather and analyse information about invasive alien species and identify priorities for action. This network helps to raise awareness of the problem and facilitate numerous exchanges of experience among the entities. This initiative will result in the compilation of the most comprehensive report to date on the status of invasive alien species in overseas French territories. This report will be published in June 2008. It will assess the impacts of invasive species, the current state of research, the legal tools available to deal with them, and the programmes and strategies implemented to combat them. It will also put forward a series of recommendations aimed at preventing and combating this problem. This French overseas territory-wide initiative is a tangible example of collaborative action among several overseas territories aimed at acquiring an understanding of a common problem and facilitating exchanges about good practice.



Soubeyran 2008

3.2.2 New threats resulting from climate change

Impacts on biodiversity

There are very few scientific data about the observed or potential impacts of climate change on the biodiversity of the Reunion Island. Island experts who were consulted do not believe that climate change poses a serious threat to the island's biodiversity. Indeed, actual or potential threats brought by climate change may seem negligible when looked at against the direct impacts suffered by the island's biodiversity, such as direct destruction of habitats or the growth in the number of invasive alien species. Nonetheless, it is more than likely that over the next few decades, climate change will seriously affect the island's natural forests. The 193 natural habitats on the Reunion Island are often highly localized, and their distribution over the different slopes is dependent on a very delicate balance between humidity and temperature which is likely to be disrupted by climate change. A rise in temperatures could lead to the uphill migration of plant species, resulting in the potential degradation of montane forests and an increase in opportunistic species to the detriment of more fragile species. That said no predictions have been undertaken to assess the possible impacts of climate change on terrestrial biodiversity of the Reunion Island. Today, it seems crucial to carry out such an assessment in order to formulate more precise hypotheses, which can be taken into account in the habitat management and protection policies currently under implementation.

At the marine level the ecosystems most at threat from climate change are without doubt the coral reefs. In 1983, the first ever coral bleaching event was reported on the island (Guillaume et al., 1983). In 1998, during the major heat wave which affected the whole of the Indian Ocean, the Reunion corals were largely spared. The bleaching remained fairly minor, while the reefs of the western Indian Ocean were severely bleached with a resulting high coral mortality rate (see Box 3.7) (Quod, 2000). Since then, a few minor, but recurring, bleaching events have been observed on the Reunion Island in 2001 (Turquet et al., 2002), in 2003 (Turquet et al., 2003), in 2004 (Nicet and Turquet, 2004), and again in 2005. The state of the coral reefs is monitored by the Reunion Island Marine Park, in collaboration with the *Laboratoire d'Écologie Marine of the University* of the Reunion Island. An increase in the number of bleaching events could seriously weaken the corals of the island, with severe consequences for all the associated fauna and for the protection of the coastal areas from ocean swells. Similarly, a rise in sea level will probably lead to erosion of the beaches and coastal ecosystems. A combination of these phenomena and a rise in the intensity of tropical storms is likely to have serious repercussions on the coastal areas. That said, there are currently no global projections or specific monitoring of these areas.

Socio-economic implications

Some 82% of the population of the Reunion Island is concentrated on the coastal strip, where the population density is three to four times higher than the island average. Rising sea levels, the diminishing protective role of the coral reef and an increase in tropical storms intensity will have a potential impact on the infrastructure of the low-lying areas.

The Reunion tourism sector would appear, at first glance, to be less vulnerable to climate change than that of the Caribbean or Polynesian islands, because it is not exclusively dependent on the quality of the beaches and the coral reefs.

Box 3.2: Climate Change and Toxic Micro-Algae

By converting CO_2 in the water into organic compounds through a process of photosynthesis, micro-algae constitute the basis of the marine food chain. But some micro-algae, about 2% of this biological family, are able to produce toxins that are poisonous for marine fauna and humans. A census of potentially harmful micro-algae on the Reunion Island was carried out in 1999 (Hansen et al., 2001). During this study, 21 species of benthic dinoflagellates were identified on the island. Among this group of algae were most of the toxic species responsible for massive mortality among fish as well as human intoxication. Species of the Chaetoceros genus, for example, have spines and silks which can damage fish gills and affect fishing and aquaculture. Ciguatera, a common food poisoning in Reunion is also caused by a high concentration of a particular dinoflagellate (*Gambierdiscus toxicus*) (see Box 4.5).

Climate change could lead to a surge in the number of certain toxic algae. An increase in water temperature could lead to faster development of some opportunistic species. Moreover, corals that have been degraded by successive bleaching events provide an ideal breeding ground for the development of these organisms (Quod, personal communication).

J. P. Quod.

Caulerpa algae bloom in Réunion island

J.P. Quod.

The Dinoflagelate Prorocentrum produces diarrhoeal toxins

Some of the island's tourist attractions, like the volcanic landscapes, will survive regardless of what happens. However, a degradation of the beaches would nonetheless diminish the island's attractiveness, and damage to the natural landscapes of the National Park cannot be ruled out. Similarly, an aggravation of cyclonic phenomena could also damage the tourist infrastructure and the image of the Reunion Island.

Finally, climate change could also have a negative impact on public health, through an increase in the number of vector-borne diseases or the development of micro-algae that are harmful to human health and marine breeding grounds (see Box 3.2).

Response to climate change

The Reunion Island is one of the most advanced regions in terms of energy efficiency. As part of its response to the challenge of climate change, the Reunion Island is currently developing an effective strategy for mitigation. It is also implementing a commitment to managing energy consumption through the use of renewable energy sources. Numerous activities have been implemented over the last few years; actions that should be strengthened within the framework of the Reunion 2030 programme (see Box 3.3). In collaboration with the tropical and sub-tropical ORs and OCTs, the Reunion Island is also responsible for coordinating an ambitious European programme to create a network of information about current research and sustainable management of biodiversity: the NET-BIOME Programme (see Box 3.4).

Box 3.3: Reunion 2030: An Ambitious Vision for Mitigation

Launched in February 2008, Reunion 2030 is an ambitious development project whose objective is to make the Reunion Island entirely energy self-sufficient by 2030. This process could make the Reunion Island a model of sustainable development for the rest of the overseas territories and for the world as a whole. The different activities foreseen as part of this project are centred on the development of clean transport (like the Saint Denis tram-train), the production of renewable energy, energy storage, the creation of high environmental quality (HEQ) habitats, and sustainable tourism. This project aims to create 15,000 energy and environment-related jobs, and rejuvenate the island's economy. The Reunion Island, very advanced in the field of sustainable development, currently produces 40% renewable energy through installations like the Bois-Rouge thermal power station which uses bagasse (a sugar-cane waste); the Saint-Rose wind farm; the hydro-electric power plant; and the photovoltaic farm (the largest photovoltaic farm in France). Other large-scale projects are in the pipeline, including the construction of a geothermal power station in the Plaine des Sables area, on the Fournaise massif. There are disagreements over the location of this power station, because it is in the heart of the national park, currently going through the process of inclusion on the UNESCO List of World Heritage sites. Very careful studies are

Conseil Régional

Solar pans in Reunion island

needed to assess the potential impact of this power station on the environment as a whole, as well as to assess compensation plans. The development of clean energy must be carried out in harmony with biodiversity and must not become an added threat to the natural areas.

Box 3.4: NET-BIOME: Overseas Europe-Wide Research Coordination

NET-BIOME is a project of the 6th Framework Programme (FP) for Research and Technological Development of the European Union. This project is based on the Reunion Island. For the first time, it unites around a common objective the seven ORs and most of the tropical and sub-tropical OCTs belonging to five European countries (France, the Netherlands, Portugal, Spain and the United Kingdom). These territories are home to an exceptional marine and terrestrial biodiversity that is fundamental to the sustainability of their economic development (mechanisms for the management and economic valuation of biodiversity include agriculture, fishing, tourism, etc.). However, their environments are more exposed to the impacts of climate change, natural disasters and human activities than the rest of Europe. The objective of NET-BIOME is to enhance cooperation and coordination of biodiversity research for sustainable development. Concretely, it seeks to enhance the value of all the assets of the ORs and the OCTs in order to develop strategies and original models

netbiome

aimed at ensuring the sustainable management of biodiversity. These will then be scaled up and rolled out across continental Europe and shared with third parties that have territories within similar regional vicinities (Irissin-Mangata, personal communication).

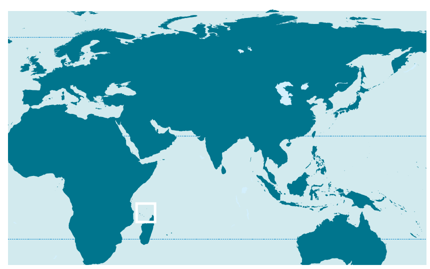
Maéli

Mayotte

MAYOTTE

3.3 Mayotte (France) OCT

Number of islands:	2 islands and 18 islets
Population:	216 306 (2008)
Area:	374 km²
Population density:	578,4 inhabitant /km²
GDP/inhabitant:	2 200 €/ inhabitant (2002)
Unemployment rate:	25 % (2007)
Economic activities:	Agriculture and fishing



Mayotte is a French departmental entity situated in the Comoros archipelago, to the north-west of Madagascar. The two principal volcanic islands are surrounded by 18 islands and ringed by a double coral reef. Since 2001, Mayotte has been involved in a political process which could, in the next few years, result in it achieving the status of overseas territory (OT), or even of European outermost region (OR). Over the last 30 years Mayotte has experienced an impressive demographic explosion. Its population of some 60,000 inhabitants has multiplied by 3.5 in less than 40 years to reach 216,306 inhabitants today. With a population density of 578.4 inhabitants per km², Mayotte today is the most densely populated of all the European overseas territories. Unemployment in this territory, which was 25% in 2007, remains high. The main economic activities are subsistence farming, export agriculture (ylang-ylang and vanilla), aquaculture and fishing. Some 120 tonnes of fish were exported from the territory in 2002 (PECE, 2006). With a sleeping capacity of 355 beds, Mayotte's tourist activity is still very much in its infancy, but ecotourism is seen as a promising development for the island.

3.3.1 Current state of biodiversity

Remarkable habitats and species

With about 1000 species of vascular plants inventoried in 2005 in an area of 354 km², Mayotte is home to one of the richest collections of tropical insular flora in the world in terms of species density (Labat, 2003). However, the island's terrestrial ecosystems are highly degraded. A few iconic species such as roussettes, lizards and the Maki (*Eulemur fulvus*), an endemic lemur, live in the last remaining vestiges of the island's natural forest and agro-forestry areas mostly.

l'argentin

Mayotte lagoon is one of the biggest lagoon in the world

Mayotte is surrounded by a lagoon that stretches 1,100 km², one of the largest in the world, enclosed in a 196-kilometre reef. Very rare phenomenon, the lagoon is bordered by an 18-kilometre double-reef on South West of the island (less than 10 double reefs are known on earth). This exceptional configuration offers an impressive diversity of corals (coral reefs, fringe corals, internal corals, pinnacles, etc.). More than 530 species of molluscs and about 700 species of fish have been observed in Mayotte (Arnaud, personal communication). The island is also home to a remarkable diversity of marine mammals, with 22 species inventoried (or about a quarter of all species in the world). Among them, 12 species of dolphins and the emblematic dugong (*Dugong Dugon*), a particularly threatened creature believed to be the original mythical mermaid. Two species of turtle breed on the island's beaches, the Hawskbill turtle (*Eretmochelys imbricata*) and the Green turtle (*Chelonia mydas*). Finally, Mayotte has 735 hectares of mangroves and 760 hectares of seagrass beds which are home to 270 species of algae and 11 species of sea grasses (Loricourt, 2006). Six marine protected areas cover a total area of 4,548 hectares, only 3% of the lagoon's area (Gabrié 2007). Human and financial resources remain too scarce to guarantee the effective management of these protected areas.

Current threats

The primary forest of Mayotte has almost completely disappeared because of antiquated agricultural practices, but also because of pressure exerted on the land by recent population growth. Today, it only covers 3% of the island (Pascal, 2002). All the remaining natural forests of Mayotte are threatened. The most worrying situation is undoubtedly that of the dry forests and the mesophiles, of which only 360 hectares and 60 hectares respectively remain (Caballé, 1996). The most important threats come from the fragmentation and destruction of natural habitats to make way for the development of infrastructure and roads, but also the increase in the number of invasive alien species which are strangling the natural vegetation. For example, the Indian laurel *(Litsea glutinosa*), an invasive species of Lauraceae, covers over 9% of the surface of the island (Labat, 2003). Over the last 30 years, heavy erosion on the slopes of the lagoon caused by deforestation, slash and burn agriculture, and over-grazing has caused the Mayotte lagoon to silt up leading in turn to a general deterioration of the island's reefs and seagrass beds. The beaches of Mayotte are still relatively well preserved, but an increase in the number of hotels is likely to disrupt these very fragile environments. The island's recently approved Management and Sustainable Development Plan (MSDP), foresees the

Whit Welles

Humpback whales (*Megaptera novaeangliae*) breed in Mayotte before migrating to the Antarctic ocean during the austral summer creation of nine permanent coastal tourist sites that will be subject to very specific conditions governing the integration of the infrastructure within the natural environment.

3.3.2 New threats resulting from climate change

Impacts on biodiversity

There are very few reliable data about the actual or potential impacts of climate change on Mayotte's biodiversity. Just as experts on the Reunion Island perceive climate change as a secondary threat, so the same is true of Mayotte. More pressing ecological challenges identified include deforestation, progressive sedimentation in the lagoon, invasive plants, as well as water scarcity and waste disposal. Actors in the field fear that climate change will monopolize the region's slim research capacities and compete with other challenges that they consider to be more pressing. That said climate change is likely to affect Mayotte in a variety of different ways.

The last remaining vestiges of the island's natural forest are likely to be affected by changes in climate conditions. The likely migration of plant species towards higher ground could destabilize the natural equilibria and speed up the spread of certain invasive alien plant species. The mountain-ridge tropical rain forests are particularly threatened by rising temperatures, because they will not be able to migrate any higher since they are already situated at the upper limits of their bio-climatic zones.

The beaches and coastal ecosystems are also particularly vulnerable to climate change. Rising sea levels could erode

Anthony Metayer

The Brown Maki (*Eulemur fulvus*) is found on Mayotte's rain forest

the hitherto very well preserved beaches of Mayotte and threaten the fauna and flora that depend upon them. The degradation of the beaches could result in collateral damage to the turtle populations that use them to lay their eggs. These species are also under threat from rising temperatures which could influence the conditions in which their eggs incubate and limit their reproductive capacity (see Box 3.5).

In the last 25 years Mayotte has experienced two serious coral bleaching events. Between 1982 and 1983, close to 36% of the fringe reefs were bleached. In 1998, the heat wave which swept through the Indian Ocean led to the bleaching of 90% of the corals on most of the outer slopes of the island. Results of monitoring activities undertaken over the last nine years have revealed that the corals have begun to rejuvenate, notably those on the outer reefs

Box 3.5: Temperature-Dependent Sex Determination (TSD) in Marine Turtles

Because of their system of sex-determination, marine turtles can be directly affected by climate change. Instead of sex being determined genetically – as in most vertebrates such as mammals and birds - the turtle's individual sex is determined by the temperature at which the eggs incubate during the middle third of the incubation period (Yntema and Mrosovsky, 1982). There is therefore a "pivotal" temperature where a 1:1 sex-ratio is produced, and which ultimately determines the trend of the male/female ratio. All marine turtles exhibit a male-female pattern of sex determination (Wibbels, 2003), i.e.,temperatures below the pivotal temperature generate more males and those above the pivotal temperature generate more females. A rise in temperature around the beaches increases the number of females while a drop in temperature favours the development of males (Godley et al., 2002). Climate change therefore has the potential to disrupt the natural male/female ratio of marine turtle populations, with serious consequences for the reproductive potential and survival of these species. Even a change of 1 to 2ºC in incubation temperature can make a considerable difference to the sex ratio of the hatchlings (Mrosovsky and Yntema, 1995), and a temperature change of 3ºC or less could potentially shift sex ratios from all male to all females or vice-versa (Wibbels, 2003), making climate change and global warming a major conservational concern for Temperature-dependent Sex Determination (TSD) species like marine turtles. Turtles are thus good indicators against which to gauge the biological impacts of climate change, given that a relatively limited temperature increase will have direct consequences for their survival. Added to the threat posed by temperature increases, is the danger posed by the probable rise in sea levels which could lead to the disappearance of a large number of turtle nesting sites (see Box 2.11).

The Island of Mayotte is home to 163 nesting sites regularly used by Hawksbill and Green turtles (Gargominy, 2003). This abundant and relatively well-preserved turtle community is one of the island's principal natural treasures and a first-rate ecotourism attraction. That said, these species are under threat from far more direct pressures than climate change, such as poaching (which affects about 2,000 turtles every year) (Tortues de Mayotte 2007) and the silting up of the lagoon which is smothering the reefs and seagrasses upon which they depend for their food. The activities implemented by the Department of Forests and Agriculture and associations with a view limiting these human-induced impacts have started to bear fruit. The Green turtle populations in Mayotte have begun to stabilize (Bourjea et al., 2007).

Mathieu Cmpain

Green turtle (*Chelonia mydas*) on N'Gouja where levels of coverage and diversity are probably close to 1998 levels (Quod, 2000). On the fringe reef there are more mitigated results with the slowest levels of growth recorded being observed in those areas directly exposed to the impacts of human activities: poor sewage treatment, land-based sedimentation caused by deforestation, etc. Measures aimed a protecting the Mayotte lagoon, the island's principal natural treasure, have taken on a new urgency. Given the demographic explosion in Mayotte, the preservation of the lagoon will be no easy task and will present a major challenge over the next few years.

Migratory marine mammals, iconic species of Mayotte's natural heritage, could also be affected by climate change during their Southern Ocean feeding season (see Box 7.6).

Socio-economic implications

There is an extremely strong demand for land in Mayotte, especially in the low-lying coastal areas which tend to be the most densely populated. Coastal erosion caused by rising sea levels could result in the migration of human populations towards the interior and exacerbate pressure on the last remaining natural ecosystems of the island's interior. Mayotte's economy is highly dependent on the fishing sector. By increasing the number of coral bleaching episodes, climate change could result in a decline in the populations of reef fish (see Box 3.8). A decrease in fish stocks could affect both subsistence and commercial fishing, and have a non-negligible impact on the island's economy. The degradation of the corals, which took place in Mayotte in 1998, also led to an explosion of the toxic micro-algae (*Gambierdiscus toxicus*) which cause ciguatera, human food poisoning caused by eating infected fish. These algae proliferate on degraded reefs. Their density increased more than 150 times between 1998 and 1999 (before and after the major bleaching episode) at monitored sites in Mayotte. That said, no significant increase in the number of cases of food poisoning was observed on the island in 1999 (Quod, 1999).

Responses to climate change

In Mayotte, a number of actions are undertaken by schools and village associations to raise awareness on the natural island heritage conservation. National and territorial public services support actively education initiatives for sustainable development (EEDD initiative, Education à l'Environnement en faveur du Développement Durable), with the technical contribution of the Ecole et Nature association. The Sandwatch project, funded by UNESCO, is one of the education projects supported by the EEDD initiative. It regularly monitors the island's beaches and organizes activities to raise awareness of the importance of preserving these environments (see Box 3.6).

Box 3.6: Action for Awareness: The Sandwatch Project

Sandwatch is a long-term project whose objective is to monitor the state of the beaches and raise awareness among island communities of the problems and conflicts affecting beaches. It aims to instill in individuals, especially children, an understanding of the fragile nature of the marine and coastal environments by involving them in concrete projects to monitor and protect of these environments. The Sandwatch project was started in the Caribbean in 1999 as part of a UNESCO initiative. Since then, it has been picked up and implemented by non-governmental organizations, schools, teachers, students and members of communities in islands as far afield as the Cook Islands in the Pacific, the Bahamas in the Caribbean, and Mayotte in the Indian Ocean. The classes and organizations involved in this project are responsible for regularly monitoring and making a note of simple characteristics of some designated beaches around their islands (erosion, accretion, sand composition, fauna and flora, water quality, human activities, quantity of debris and litter). These data are subsequently compiled and analysed by the scientific community, but also locally by participating groups of school children and local associations. They are communicated to the rest of the population through conferences, news reports and exhibitions, but also through artistic media and play activities such as illustrations, poems and games to raise awareness. In Mayotte, Koungou College is actively involved in the Sandwatch project. The activities organized by the students, with the support of local associations, range from monitoring the island's turtle populations, to observing egg-laying, to preventing poaching, to the planting of mangroves, to rubbish collection. The students organize exhibitions of their work and meet with other participants in the project by participating in other events taking place on the island (Gabriel, personal communication). Their activities, which are reported in the media, serve to raise local awareness of the fragility of coastal ecosystems.

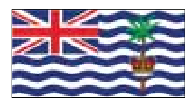
Pascale Gabriel

Pascale Gabriel

Sandwatch activities realized by the Koungou high school

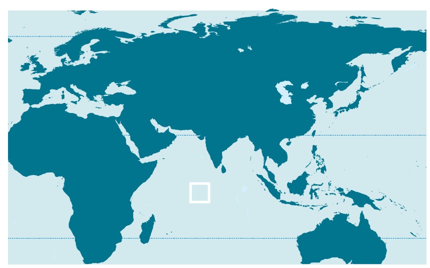
John Turner

British Indian Ocean Territory (Chagos Archipelago)



3.4 BIOT (United Kingdom) OCT

Number of islands:	5 atolls, 55 islands
Population:	4 000 inhabitants (2008)
Area:	60 km²
Population density:	N/a
GDP/inhabitant:	N/a
Unemployment rate:	N/a
Economic activities:	Military presence



The British Indian Ocean Territory (BIOT), also known as the Chagos Archipelago, is situated half way between Africa and Indonesia, to the south of India and the Maldives. The territory is made up of 55 coral islands spread over five atolls. It includes the Great Chagos Bank, the largest atoll in the world. The emerged area of the territory is 60 km², but the Chagos EEZ extends over an area of half a million km². The islands are of coral origin and never exceed 4 metres in altitude. The largest island of the archipelago, Diego Garcia, hosts an American military base. In 1967, the 950 native inhabitants of the Territory, the Chagos Islanders or Chagossians, were evicted from the island and sent to Mauritius and the Seychelles to make way for the construction of the military base. Today, there are approximately 2,000 American military personnel and a broadly similar number of civilian contractors on the island. There is no industrial or agricultural activity on the island, nor are there civil aviation companies or tourist activities. The only civilian economic activity is fishing. Fishing licenses bring in an estimated US$ 1 million per year in revenues for the BIOT administration and are used to part-fund the Fisheries Protection vessel.

3.4.1 Current state of biodiversity

Remarkable habitats and species

The Chagos archipelago is one of the world's best preserved tropical island systems. These islands provide sanctuary for a multitude of species of seabirds. The island is home to 10 Important Bird Areas (IBA) recognized by BirdLife International, including Barton Point Reserve in Diego Garcia, which is home to one of the world's largest populations of Red-footed Boobies (Sula sula). More than 4,000 were inventoried in 1995 (Carr, 2006). The well-preserved beaches of the Chagos islands provide ideal nesting conditions for two species of marine turtles. The crystal clear waters of the archipelago are host to over 220 species of coral spread out over 25,000 km² of well-protected reefs, as well as several species of whales, dophins and sharks (Sheppard, personal communication).

Current pressures

Vast plantations of coconut palms have diminished the terrestrial biodiversity on some islands of the Chagos archipelago. In addition, invasive rats and cats have devastated nesting seabird populations on most of the islands. Illegal harvesting of sharks and sea cucumbers is a major threat to the marine environment. However, the marine ecosystems are relatively well preserved. Indeed, the level of water pollution around the Chagos archipelago is remarkably low. Analyses carried out in 1996 and 2006 showed that the waters were the cleanest ever tested in the world for a range of substances (Guitart et al., 2007). These waters act as a global benchmark.

John Turner

Red-footed booby (*sula sula*)

3.4.2 New threats resulting from climate change

The Chagos Islands are the most well preserved in the central Indian Ocean. They thus provide an ideal environment for the study of the effects of global warming on island ecosystems, and on coral reefs in particular. These reefs serve as global control sites; they can be compared to reefs in inhabited regions, which are subject to numerous additional pressures to climate change and which as a result have often sustained more damage.

In 1998, a rise in the water temperature caused massive coral bleaching throughout the Indian Ocean. The subsequent mortality was measured with great precision on the Chagos archipelago, where it reached 95% in some areas (see Box 3.7). The reefs regenerated themselves fairly rapidly, in the shallow waters at least (Sheppard et al., 2008). This unique resilience probably arises from the fact that they were remarkably healthy prior to this event. Studies indicate, however, that the degradation of the reefs as a result of the 1998 bleaching event nonetheless had direct impacts upon the fish communities that lived within these ecosystems (see Box 3.8).

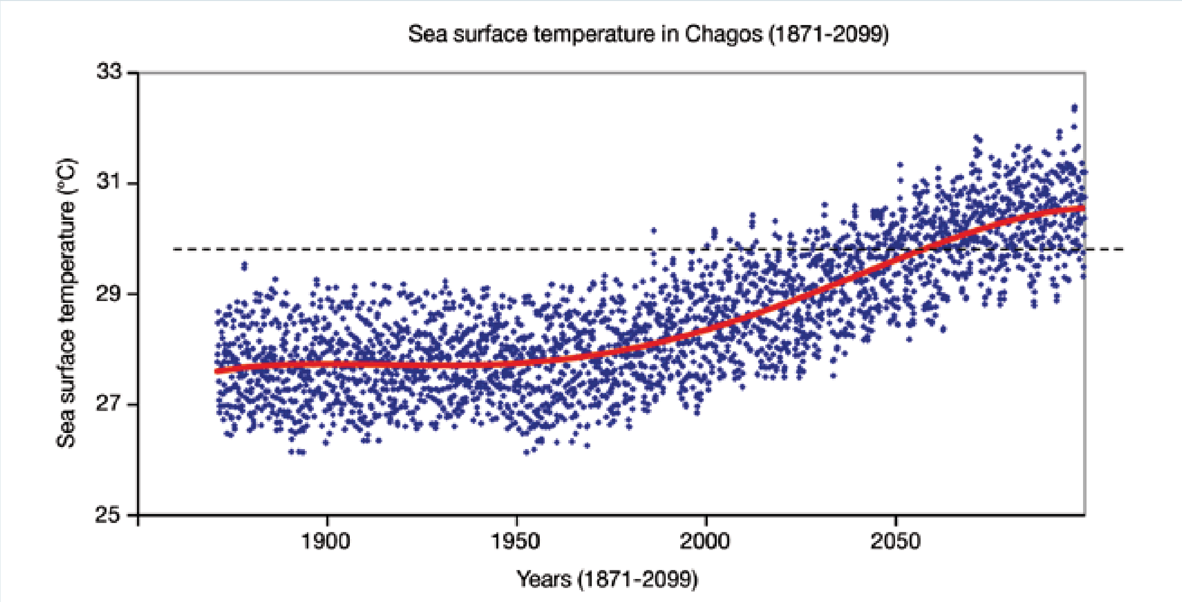
Over the last 20 years, the sea level in the Chagos islands has risen by 5 milimetres per year. The coastal areas of these very low-lying islands are therefore particularly vulnerable to erosion. In 2006/2008, many instances of erosion were identified on the islands of Diego Garcia and Salomon (Sheppard, personal communication). On Diamant Island, 40-year old coconut palms were assailed by the waters all along the coast and began to perish (see photo). These observations bear witness to a significant change in the coastal features. This phenomenon is partly both natural and cyclical; therefore it cannot be imputed to climate change with any degree of certainty. However, the rise in sea level is accelerating the general process of erosion. The disappearance or degradation of the beaches could seriously impact upon the marine turtles that use these ecosystems as breeding grounds.

John Turner

Coast erosion and coconut trees dying on Diamant island, likely provoked by a recent sea level rise

Box 3.7: 1998: Massive Bleaching of the Indian Ocean Corals

In 1998, the entire Indian Ocean experienced unusually high water temperatures as a result of the El Niño weather system. Massive coral bleaching was observed in this region and the rest of the world. It is believed that an estimated 16% of the world's corals perished that year (Marshall, 2006). In the Chagos Islands, the surface temperature of the water remained at approximately 30°C over a period of a few months. Over 95% of corals were bleached in some areas. The depth of the affected coral ranged from 15 metres around the atolls in the north, to as much as 30 metres around Diego Garcia, situated further south (Sheppard, 2003). The recovery of the coral in this region was relatively swift (Sheppard, 2008). However, since that date, two subsequent bleaching events have been observed. They were not as long-lasting as the 1998 episode, but in some places were sufficiently serious to kill a large number of corals. A study published in the journal Nature presents a theoretical modelling of the surface-water temperatures in the Chagos between 1900 and 2100. This model is based on historical data as well as on projections (Sheppard, 2003) (see graphic). Starting in 2050, average annual temperatures of 30°C, which led to massive coal bleaching in 1998 (shown as a dotted line on the graph), could well become the norm in this region. Following a bleaching event, corals need approximately two years to recover. Repeated heat waves predicted for the Indian Ocean could hinder the recovery capacity of the damaged coral and imperil these species. Without corals to protect the coasts from ocean swell, the very existence of these islands could be threatened.



Observation and projection of sea surface temperature in Chagos from 1871 to 2099. The 30°C temperature (dashed line), that provoked massive coral bleaching in 1998, could become an annual average for the region in 2050 (Sheppard 2003).

Charles Sheppard

Egmont atoll coral reefs before the 1998 coral bleaching event

Box 3.8: Coral Bleaching: A Threat to Reef Fish

Most reef fish are directly dependent upon the corals for their food, protection, reproduction and ultimately their survival. In the event of the massive mortality of their coral environment, these fish will be condemned to a rapid decline. Following the 1998 coral bleaching episode, the overall density of the reef fish populations around the Chagos islands declined by as much as half in the seriously degraded areas (Graham, 2007). In the Seychelles, more detailed studies carried out point to a similar trend. In order to observe the long-term impacts of the 1998 bleaching event on the fish communities of the archipelago, the abundance and size of 134 species of 16 families of reef fish were measured at 21 sites over a total area of 50,000 km² of coral. The observations were compared with similar data gathered in 1994, prior to the bleaching event. Preliminary results indicate that the diversity and density of the reef fish have severely declined since 1994. The abundance of certain fragile species has seriously diminished. These include smaller species that require shelter from predators, or those that feed directly on live coral. The observations go so far as to show that four species of fish may even be locally extinct: one species of butterfly fish, one species of damsel fish and two species of wrasses. Thus, through coral bleaching, climate change has direct consequences on the entire ecosystem and an important impact on the abundance and diversity of fish stocks.


Olivier Roux

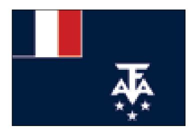
Bleached corals and reef fishes


Charles Sheppard

Egmont atoll coral reefs after the 1998 coral bleaching event

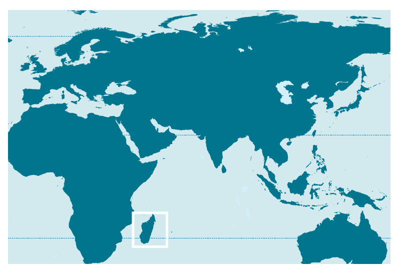
JIUCN/Jean-Philippe Palasi

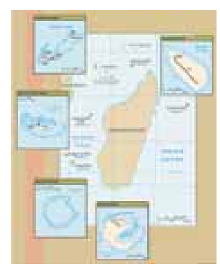
Scattered Islands



3.5 Scattered Islands (France) OCT

Number of islands:	6 islands
Population:	< 20 inhabitants
Area:	44 km²
Population density:	N/a
GDP/inhabitant:	N/a
Unemployment rate:	N/a
Economic activities:	Military presence





The Scattered Islands of the Indian Ocean are one of five districts of the French Southern and Antarctic Territories (French acronym TAAF). The TAAF are French overseas territories (FOT) and part of the European overseas countries and territories (OCT). Although the Scattered Islands are not an overseas territory in their own right, they are being treated in this document under their own heading because their climatic and environmental characteristics are very different from those of the other districts that make up the TAAF (see section 7.6).

Sourrounding the island of Madagascar, the Scattered Islands include Europa Island, Bassas da India, Juan de Nova Island, Tromelin Island and the Glorioso archipelago which includes Grande Glorieuse and the île du Lys. The emerged area of these islands is only 44 km², of which the Island of Europa, the largest of the islands, accounts for 30 km². However, the vast marine environment that constitutes their exclusive economic zone extends over an area of 640,000 km². The Scattered Islands are all of coral origin and none are more than a few metres in altitude. Bassas da India is a very low-lying atoll that is almost entirely submerged at high tide. The only human presence on the islands consists of military personnel, meteorologists and occasionally scientists. Europa Island in particular hosts a permanent population of 14 soldiers who rotate at 45-day intervals.

3.5.1 Current state of biodiversity

The vegetation of the Scattered Islands is very distinct from one island to another. Europa Island houses a euphorbia forest which grows in rocky soils, often accompanied by ficus, separated by clearings. This forest provides vital nesting grounds for Boobies and Frigate birds. The mangroves, which occupy part of the central lagoon of the island, also serve to distinguish Europa Island from the other

Scattered Islands: it is the only one of the Scattered Islands to have virtually intact native vegetation. On Juan de Nova Island, the vegetation is almost entirely made up of coconut palms, while Tromelin Island is home to a few shrubs and herbaceous plants. Grande Glorieuse was once covered by a dense forest that has all but disappeared, replaced a century ago by a now abandoned coconut palm plantation (15,000 feet), an ancient sisal plantation, and a sometimes dense spiny shrub vegetation. The Scattered Islands are host to very large colonies of marine nesting birds, including several species of White-tailed Tropicbird, terns, Boobies, and Frigate birds. Large numbers of marine turtles also come to lay their eggs on the water fronts of the islands of Europa and Tromelin (Gargominy 2003).

The Scattered Islands are almost entirely free of direct human impacts. Only a few introduced species exert pressure on the island's biodiversity, such as wild goats that were introduced to Europa Island and which have an impact upon the native vegetation; and the rats, which pose a threat to birds' nests and the young turtles. The eradication of introduced species is considered a priority in the management of these islands. The large fringe reefs around the islands of Europa, Juan de Nova and Bassas da India are home to a large variety of corals that were perfectly preserved right up until the 1998 bleaching event; they remain valuable model ecosystems, since they subsist in the absence of direct human pressure. However, scientific knowledge of the reefs remains very limited. Finally, the Scattered Islands, along with Mayotte and the Comoros, constitute one of the most globally important geographical areas for the preservation of the genetic diversity of Green turtle populations (Lauret-Stepler et al., 2007).

3.5.2 New threats resulting from climate change

Impacts on biodiversity

Because of their coral base, the Scattered Islands are particularly vulnerable to climate change. A rise in water temperatures will probably lead to more regular bleaching episodes. As a consequence, the degraded reefs run the risk of no longer being able to provide the coasts with protection from ocean swell. In addition, rising sea levels could increase the erosion of these fragile coral lands. Climate change also presents a threat to the turtle communities who come to the islands to reproduce, through the erosion of the beaches, the disappearance of breeding grounds, and a possible change in the sex ratio among turtles. However, none or very few scientific data exist about the bleaching of the corals or the erosion of the beaches among these islands. Yet, the Scattered Islands could provide model reference points to measure the impact of climate change on terrestrial and marine ecosystems in environments that are devoid of all human impacts. Europa Island, in particular, could be used as an ecological beacon for the entire Indian Ocean (see Box 3.9).

Box 3.9: Europa Island: A Potentiel Climate Change Beacon

Europa Island is a sanctuary of well-preserved terrestrial and marine biodiversity. It has a unique profile, with a shallow interior lagoon which drains out at low tide, a mangrove area of over 700 hectares and a vast euphorbia forest. It hosts several species of migratory birds, of which 13 come to the island to reproduce. It is also home to the largest communities of Red-tailed Tropicbird (*Phaethon rubricauda*) and Sooty terns (*Sterna fuscata*) in the eastern Indian Ocean. It is one of the globally most important nesting grounds for the Green turtle (*Chelonia mydas*); 8,000 to 15,000 females come to lay their eggs on the island each year (Le Gall, 1986). The island's fringe reef hosts a large coral population. With its practically intact flora and fauna, Europa Island is an important point of reference for the entire Indian Ocean. Despite the introduction of a small number of species, including goats, and continuous human presence since the 1950s, Europa Island has been largely spared from the impacts of human activity which affect the other islands of the region, such as habitat destruction, over-exploitation of species, soil erosion and sedimentation in the lagoons. However, the island will not be untouched by the effects of climate change. Europa Island could therefore act as an ecological beacon and serve as a potential witness to the impacts of climate change in the region, in the same way that the Chagos archipelago can in the central Indian Ocean. In this well-preserved island, it is possible to distinguish the changes to the ecosystems that are a direct result of climate variations; while on other islands, more exposed to the impacts of human activities, it is not easy to distinguish between the combined effects of local human impacts and global pressures. The scientific potential of Europa Island remains largely unexploited at present; despite the fact that the data that have been collected on the island could serve as a regional, or even global, point of reference to monitor the impacts of climate change on island-based biodiversity in tropical areas.

Galejade

Europa island

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3.6

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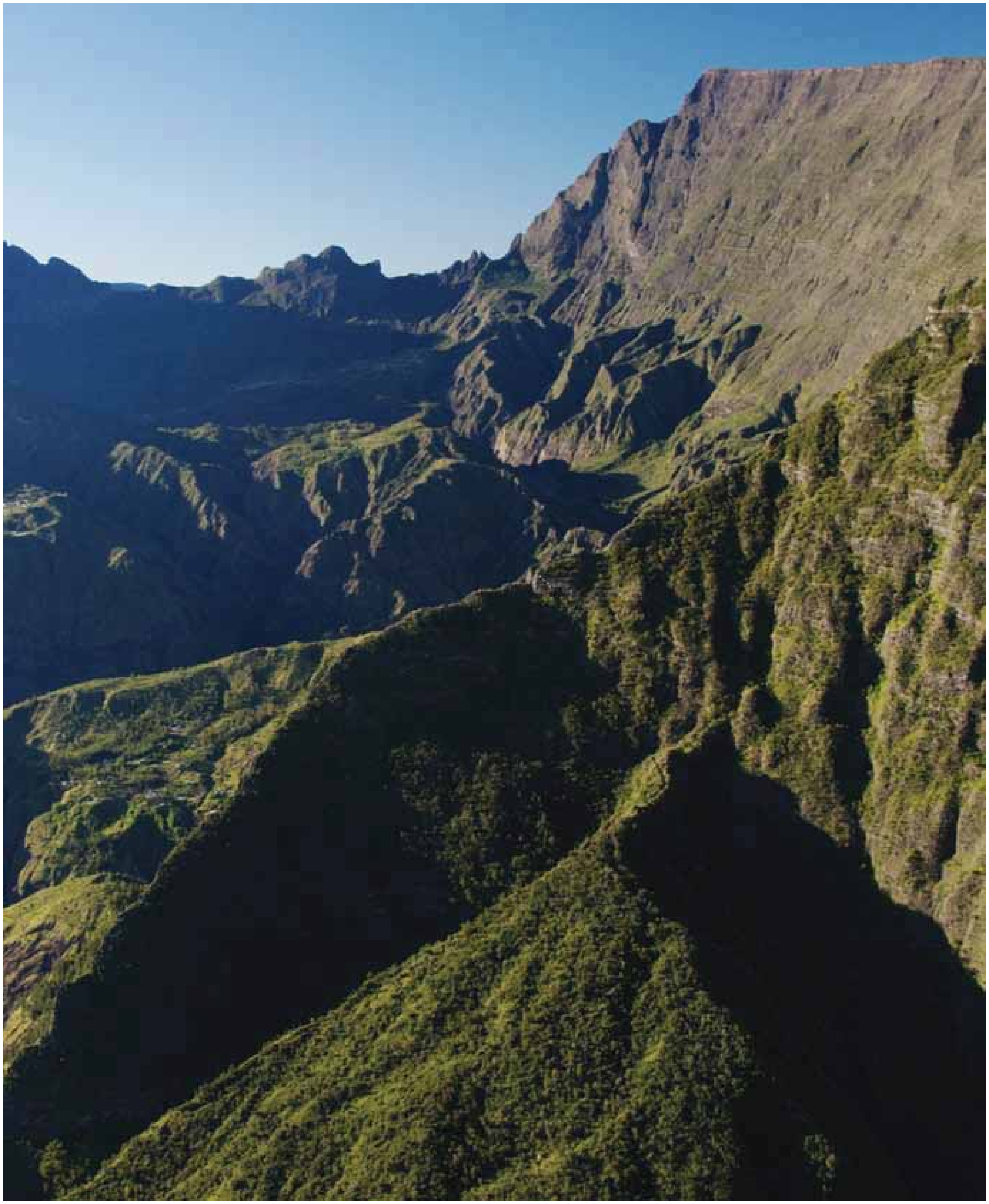


Christophandre

Mafate Circus, at the center of Réunion Island

4. South Pacific

Author: Jérôme Petit

Introduction

4.1

The Pacific Ocean is a huge body of water stretching over 166 million km²; it is home to some 25,000 islands. These are divided into three groups: Melanesia to the west which includes, among others, the Indonesian islands; Micronesia to the north; and Polynesia to the east, in the New Zealand-Hawaii-Easter Island triangle. The Pacific island chain is made up of scattered volcanic islands – some of which are high and geologically recent – and much lower, older coral islands. The South Pacific includes four overseas countries and territories (OCTs) of the European Union (see Map): French Polynesia, Wallis and Futuna (France) and Pitcairn (United Kingdom) situated in the Polynesian Triangle in the middle of the Pacific; and New Caledonia (France) situated in Melanesia, 1,500 kilometres east of Australia. French Polynesia and New Caledonia are the most populated European overseas territories with 283,019 and 224,824 inhabitants respectively, while Pitcairn, with a population of 50, is the least populated political entity in the world. French Polynesia's economy is based primarily on the public sector (national grants), tourism and pearl farming, while New Caledonia's is based mainly on nickel mining. Wallis and Futuna and Pitcairn, for their part, depend on agriculture, subsistence fishing and grants from their national States.

Biodiversity

The chief distinguishing feature of the Polynesian islands is their remoteness from any continent. The island of Tahiti, for example, is almost 6,000 kilometres from Australia and 7,000 from North America, the two closest continents. Because of their isolation, the number of terrestrial species found on these islands is limited, but their level of terrestrial endemism is exceptionally high. Indeed, the few biological families which managed to reach these islands have evolved in isolation over several million years, to occupy unfilled ecological niches (a process of "adaptive radiation"). The islands of French Polynesia, Wallis and Futuna and Pitcairn are part of the "Polynesia–Micronesia" global biodiversity

Mila Zinkova

New Caledonia and its dependencies are important reproductive areas for the green turtle (*Chelonia mydas*) hotspot (Myers, 2000). French Polynesia has 118 islands, including 84 atolls, some 20% of the atolls of the planet. This territory is home to a remarkable variety of landscapes, ranging from high altitude volcanic islands to low-lying coral islands.

New Caledonia is a global biodiversity hotspot in its own right. Its biodiversity is three times greater than that of the Polynesian Islands. There are three reasons for this. First, it is in Melanesia, close to the Indonesian basin, itself particularly species-rich. Second, the unique mineral composition of its soils has greatly influenced the evolution of its vegetation. Finally, New Caledonia is not a volcanic island that emerged from the ocean, but a fragment of Pangaea, the original single continent. Numerous species were isolated early on in the planet's geological history and as a result developed in a unique manner. The rate of endemism in New Caledonia is one of the highest in the world. For example, the territory numbers 2,423 species of endemic vascular plants, while the whole of continental Europe only has 3,500 over a surface area about 500 times larger (Gargominy, 2003). New Caledonia is also home to the second longest coral barrier reef in the world, after Australia's famous "Great Barrier Reef".

Current threats

Apart from climate change, habitat destruction and the introduction of invasive species are the two greatest threats to biodiversity in the territories of the South Pacific. Bush fires and nickel mining also have important impacts on habitats in New Caledonia. For their part, the remaining natural zones of French Polynesia and Wallis and Futuna are subject to growing urbanization. French Polynesia also has to cope with countless invasive alien species which pose a threat to its endemic species. In Tahiti, for example, Miconia or Velvet tree (*Miconia calvescens*), a plant originally introduced as an ornamental species, today covers two-thirds of the territory (Gargominy 2003). The coastal waters of the South Pacific are also affected by over-fishing, land-based pollution (caused by erosion) and organic pollution (due to sewage water), especially round the main urban areas, which attack the corals. On the whole, however, the marine biodiversity of these territories remains relatively well preserved. Many reefs are still healthy, especially round New Caledonia and in the uninhabited Tuamotus islands in French Polynesia. Nonetheless, even these areas cannot escape the impacts of climate change, an added stress that is likely to have important consequences for the unique biodiversity of the South Pacific.

J. Y. Meyer

The invasive plant Miconia (*Miconia calvescens*) is present on two third of Tahiti Island

Climate projections for the region

Table 6: Variations in climate between now and the end of the century for South Pacific (IPCC, 2007).

Average for 21 global simulation models (scenario A1B). Margin of uncertainty between square brackets (25/75% quartiles).

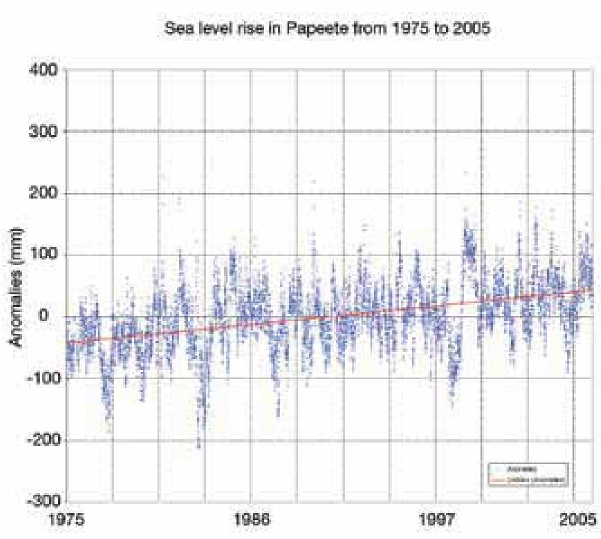
Climate indicator	Variations between 1980-1999 to 2080-2099
Air temperature	Increase of 1.8°C [+1.7 to +2] (in New Caledonia, increase from 1,8 to 2,1°C)
Precipitation	Increase of 3% [+3 to +6] (in New Caledonia, decrease from 5 to 8 %)
Extreme weather events	Increase in tropical cyclones intensity, with stronger peak winds and heavier precipitation
Sea level	Average rise of 0.35 metres (0.23 – 0.47 metres)

The South Pacific stretches over an area of several million km². Given its huge size, climate projections for the region are not uniform. Important variations are apparent between the different sub-regions (particularly between French Polynesia and New Caledonia). Overall, the IPCC predicts that average annual temperatures will rise by 1.8°C in the South Pacific between now and 2099 (see Table). This is similar to the predicted global average. However, several studies point to stronger temperature rises in the equatorial region of the South Pacific (+2.4°C north of French Polynesia) and weaker increases in the southern zone (+1.2°C south of French Polynesia). In New Caledonia, temperatures are expected to increase between 1.8°C to 2.1°C between now and the end of the century (Maitrepierre, 2006).

As far as precipitation is concerned, the figures are less clear; IPCC projections point to an average increase in rainfall of 3% over the entire region of the South Pacific between now and the end of the 21st century. Again, strong regional disparities exist. Most models foresee a strong increase in annual precipitation in the equatorial zone of the South Pacific (+20%) with a weaker increase, or even a decrease in precipitation levels, in the rest of the region. In New Caledonia, annual precipitation is set to decrease between 5 and 8% between now and 2099 (Maitrepierre, 2006). Decreases will not be very marked during the rainy season from January to March, but will be very noticeable during the dry season from August to November (as much as -24%).

Given greater the levels of warming predicted for the Central Pacific, the distribution of tropical storms in the South Pacific is also likely to change. Exact changes in the frequency and passage of cyclones through the region are still not entirely clear, however, an increase in their intensity is to be expected (IPCC, 2007).

Finally, the IPCC predicts a rise in sea levels of about 0.35 metres throughout the South Pacific, a figure similar to the global average (Church, 2006). However, variations between sub-regions will be important and the level of uncertainty remains high. A rise of 7.5 centimetres has already been observed in Tahiti between 1975 and 2005; while in New Caledonia the sea level remained almost unchanged over the same period (Sea Level Centre, 2005) (see Box 4.9).



ONERC – Sea level center

Impacts of climate change on biodiversity

Available data and scientific publications about the observed and potential impacts of climate change on the region's biodiversity are limited. At the marine level, the coral reefs are likely to be the most vulnerable ecosystems. The South Pacific corals have been affected by several bleaching episodes. However, the bleaching observed in the Pacific has not been as massive or as widespread as the episodes which affected the Indian Ocean in 1998 or the Caribbean in 2005.

The region's corals are also threatened by the likely increase in the number of tropical storms. In 2003, precise measurements were taken of the impacts of hurricane Erica on the reefs of the marine park in the southern province of New Caledonia (see Box 4.7). Rising sea levels caused by climate change also represent a serious threat to the coastal ecosystems of the region. In French Polynesia, the 84 low-lying coral islands could disappear altogether in the long term if sea levels rise significantly (see Box 4.1). The beaches and mangroves of New Caledonia are also particularly vulnerable, and some incidents of localized coastal erosion have already been observed in Wallis and Futuna.

At the terrestrial level, scientific data on the impacts of climate change are even more limited. However, some specific ecosystems will be more sensitive to expected changes than others. For instance, the subalpine forests of French Polynesia will not be able to migrate to higher altitudes if average annual temperatures rise (see Box 4.2). Furthermore, an upward migration of invasive species caused by changes in climate could threaten the last remaining populations of endemic species that have sought refuge in these hitherto relatively well-preserved zones. In particular, populations of relictual species endemic to Tahiti could be seriously threatened by the upward migration of their predators (see Box 4.3). Equally, the last remaining fragments of dry forest of New Caledonia, which are priority conservation zones, are also climate change-sensitive ecosystems. More intense droughts will increase the risk of fires, which are the biggest threat to these habitats (see Box 4.8).

N. Ferraton

Littoral submersion in Wallis and Futuna, likely provoked by a recent sea level rise

Socio-economic implications

Rising seas levels and the submersion of the coastal areas will have major economic and social consequences for the Pacific Islands; especially for the atolls of French Polynesia whose altitude, only a few metres above sea level, puts them in a fairly critical position. The consequences will be extremely serious for the local populations. This is particularly true of the inhabitants of the Islands of Tuvalu, who for the last few years have had to cope with the temporary submersion of their lands, as well as for the populations of the French Polynesian atolls who could become some of the first climate refugees (see Box 4.1). The atolls will not be the only territories threatened by rising sea levels; the submersion of the coastal zones could also have serious economic and social implications for the higher islands. Modelling, showing potential patterns of submersion, carried out in Wallis and Futuna and in Tahiti, round Papeete and the international airport, point to serious economic and social losses on these islands (see Box 4.11).

In addition, the impact of climate change on marine resources could seriously disrupt the region's economy. Black pearl farming is a pillar of the French Polynesian

Trackrecord ESA 2006

The 84 atolls of French Polynesia, laying a few meters above sea level, are directly threatened by sea level rise economy. Pearl production, with its finely tuned farming conditions, could be severely affected by changes in the temperature and acidity of the water (see Box 4.4). The tourist industry is also a very vulnerable economic sector. The attraction of French Polynesia and New Caledonia rests in the quality of their beaches, their reefs, and their famous spectacularly coloured lagoons. A deterioration of these resources, compounded by the degradation of infrastructure as a result of more intense tropical storms, could have serious consequences for this key sector for the region. Damage to the reefs could also impact upon the fish stocks in the lagoons of the South Pacific and, indirectly, on subsistence farming, still largely practised throughout this region. Food-producing agriculture, which is vital for the rural populations of these islands, could also suffer as a result of changes in climate conditions. Longer dry seasons in New Caledonia could perturb breeding conditions and reduce crop production. Similarly, in Wallis and Futuna, traditional cultivation of taro (a root plant cultivated throughout the islands of the Pacific), will be directly affected by rising sea levels (see Box 4.12).

Finally, climate change represents a serious threat to public health in the Pacific territories. The deterioration of the reefs could lead to an increase in the prevalence of ciguatera in the region (see Box 4.5), while a rise in temperatures could lead to an increase in the incidence of certain insect-borne diseases, such as dengue fever or malaria.

Responses to climate change

Strategies for adaptation to climate change are relatively limited in the region. Adaptation requires first and foremost a thorough knowledge of the way ecosystems function. It is only once this information is known that impacts can be accurately anticipated. A number of long-term ecosystem monitoring programmes are being conducted in the region. Two such examples are described in detail in this report: the Reef Check Initiative, standard monitoring of coral reefs (see Box 4.10), and the Biocode project in French Polynesia (see Box 4.6).

Jeremy H.

Tourism in French Polynesia could be impacted by the climate change effects

S. Haulliers

French Polynesia

4.2 French Polynesia (France) OCT

Number of islands:	118 islands
Population:	283 019 inhabitants (2008)
Area:	3 660 km²
Population density:	77,3 inhabitants / km²
GDP/inhabitant:	11 000 €/ inhabitants
Unemployment rate:	13% (1996)
Economic activities:	Agriculture, fishing, pearl farming, tourism

French Polynesia is a French overseas territory in the South Pacific. It consists of 118 islands spread over a maritime area of 2.5 million km² (an area the size of continental Europe). The territory is made up of five archipelagos: the Society Islands, the Marquesas Islands, the Austral Islands, the Tuamotus Islands and the Gambier Islands. It has 34 volcanic islands and 84 atolls. With a population of 283,019 (2008) spread over an area of 3,660 km² of emerged lands, French Polynesia's population density is relatively low (77.3 inhabitants/km²), and very unequal depending on the islands. Tahiti has approximately 160,000 inhabitants, of whom 100,000 are in the capital Papeete.

Fishing and coprah cultivation (dried coconut pulp) are the two principal traditional economic activities of French Polynesia. In 2001, the territory exported 2,400 tonnes of fish and 25,000 tonnes of coprah (PECE 2006). Recently, pearl farming has begun to occupy an important place on the territory's commercial balance sheet, and is now the primary export. Tourism is also an important industry; today, with some 210,000 visitors a year, it accounts for 20 to 25% of the territory's GDP. Despite this apparent diversity of activities, the economy of French Polynesia depends in part on national subsidies (and to a lesser extent, on European subsidies).

4.2.1 Current state of biodiversity

Terrestrial biodiversity

Because of the extreme remoteness of French Polynesia, its biodiversity is at once poor in terms of species numbers, but extremely rich in terms of terrestrial endemism (Meyer and Salvat, 2008). The rate of endemism is 100% for some biological families, such as gastropods, for example. French Polynesia is part of a global biodiversity hotspot which includes Micronesia, Polynesia and Fiji. The high islands of French Polynesia are home to high altitude rainforests, which are rich in endemic species and as yet relatively well preserved. They are home to the iconic Rough Tree Fern, the *Cyathea*, and an extremely diverse terrestrial malacofauna (more than 320 species of gastropods, almost all of which are endemic). These islands are also home to 893 indigenous species of vascular plants (58% of which are endemic) and 31 species of terrestrial birds (of which 22 are endemic). The coral islands for their part are less rich on account of their humus-devoid limestone coral soils and exposure to high levels of sun and air salinity. They have less than a hundred species of indigenous plants. However, the seabird life of these islands is very diverse (27 nesting species). Some atolls of the Tuamotus islands are home to some of the last remaining populations of coconut crab (*Birgus latro*), an excessively consumed, and now threatened, species.

Dan Polhemus

Endemic plants in Moorea's mountains

Marine biodiversity

With 20% of the planet's atolls, French Polynesia is home to the most diverse coral reef formations in the world. The 12,800 km² of reefs in the territory have 176 species of corals, 1,024 species of fish and 1,160 species of molluscs (Salvat et al., 2008). These reefs are among the most well-studied reefs in the world thanks to two research stations on the

IUCN/Jean-Philippe Palasi

Clown fish *(Amphiprion chrysopterus)* in Moorea's lagoon

Island of Moorea, CRIOBE (*Centre de Recherche Insulaire et Observatoire de l'Environnement*) and the Gump Station of the University of California, Berkeley. Three species of marine turtle: the Leatherback turtle, (*Dermochelys coriacea*), the Green turtle (*Chelonia mydas*) and the Hawksbill turtle (*Eretmochelys imbricata*) lay their eggs on the beaches of French Polynesia; however, the threat of poaching remains high. Since 2002, the waters of French Polynesia have been classified as a "sanctuary for marine mammals". They are host to 11 species of dolphin, two species of sperm whale, two species of Blainville's beaked whale (Ziphiidés), and the iconic Humpback whale (*Megaptera novaeangliae*). The territory also numbers several marine nature reserves, such as the seven atolls Aratika, Kauehi, Fakarava, Niau, Raraka, Taiaro, and Toau on the Tuamotus Islands (a UNESCO "Man and Biosphere" Reserve), the Scilly and Bellinghausen atolls, as well as a marine protected area on the Island of Moorea. The total surface of the terrestrial protected areas (natural parks, reserves) only amounts to 2% of the territory; the management of these resrves is hindered by a lack of human and financial capacity (Meyer, 2007).

Current threats

Invasive species, both plant and animal, are a major cause of terrestrial biodiversity loss in French Polynesia. Today, there are almost twice as many introduced species of vascular plants (1,700) as indigenous species (893 species) (Gargominy, 2003). About 600 introduced species are naturalized and 70 are invasive (Meyer, personal communication). If many introduced species are thankfully inoffensive, some are a real scourge. For example, the Miconia or Velvet tree (*Miconia calvescens*), introduced to Tahiti in 1937 as an ornamental species, currently covers 70,000 hectares of Tahiti, or approximately two-thirds of the island (Gargominy, 2003). Similarly, rats, cats, dogs and wild pigs are found throughout the high altitude islands; goats and sheep exercise considerable pressure on the plant cover. Alone, a single species of introduced carnivore snail (*Euglandina rosea*) has completely destroyed 57 species of snail of the Partula genus (see Box 4.3). The Glassy-winged sharpshooter (*Homalodisca vitripennis*), a wood-eating insect introduced in 1998, spread like wildfire with serious economic and social repercussions before being brought under control as part of a biological eradication programme (Petit et al., 2007). The Little fire ant (*Wasmania aurópunctata*), a highly toxic species for humans, was introduced recently in Tahiti and is spreading throughout the island.

After invasive species, the second most important threat in French Polynesia is the direct destruction of the natural habitats. The main areas concerned are the coastal areas of Tahiti, but also the coastal areas of the Society Islands. For example, the Temae wetland, in the north-east of Moorea, has been almost completely destroyed to make way for an international golf course and a residential area. And this despite the fact that it was the only lake on the Island of Moorea and one of the last remaining wetlands in the Society Islands. In fact, the site had been listed in the "Directory of Wetlands in Oceania" (Scott, 1993) where it was included because of its ecological importance (rainwater retention, protection of the lagoon, habitat for migratory birds).

French Polynesia's coral reefs, on the other hand, are well preserved, particularly those of the outer slopes of the Tuamotus Islands. The latter are perfectly conserved because they are entirely devoid of human impacts. Only the reefs in certain areas of the Society Islands have suffered massive degradation as a result of land reclamation around the fringe reefs, dragnet fishing to extract "coral soup", hyper-sedimentation of land-based materials caused by erosion of the hillsides, and pollution from domestic and agricultural waste-water.

4.2.2 New threats resulting from climate change

Impacts on marine biodiversity

Given its geomorphology, French Polynesia is one of the territories most at risk from rising sea levels. A large number of islands are at very low altitude and therefore particularly vulnerable to rising waters (see Box 4.1). French Polynesia has experienced seven coral bleaching episodes in the last 20 years. Although none have resulted in the extreme levels of morality observed in the Indian Ocean in 1998 or the Caribbean in 2005, significant losses of coral were nonetheless observed. In 1991, a bleaching episode resulted in 20% mortality among the coral colonies on the outer slopes of Moorea (Salvat, 1992). In 1994, a similar bleaching episode affected the region, but most of the colonies were able to regenerate without suffering excessive losses. Finally, in 1999 a last episode of bleaching affected Polynesia; mortality rates varied from one island to another (Salvat et al., 2008). Successive bleaching episodes lead to a decline in the number of lagoon fish and thus of the entire tropical marine food chain. Erosion of the beaches could also affect the turtle populations that depend upon these habitats to reproduce.

Impacts on terrestrial biodiversity

The well preserved, endemic species-rich subalpine ecosystems are without doubt the terrestrial habitats most at risk from variations in temperature and rainfall patterns (see Box 4.2). Climate change could cause plant species to migrate towards higher altitudes and result in a general

Box 4.1: Submerged Atolls?

Atolls are among the most complex and fascinating geological structures of the planet. These ring-shaped tropical islands, which sometimes exceed 10 kilometres in diameter, enclose a lagoon in their centre and are home to an exceptional diversity of marine life. It takes 30 million years for an atoll to form. First, a volcanic island emerges from the ocean. Little by little it is colonized by reefs of fringe coral. Once the volcano is extinct it becomes more dense, gradually sinks into the ocean and eventually disappears beneath the surface of the water. Only the ring of coral remains since it regenerates as the volcano subsides. An atoll therefore is the imprint of an island, or a fossil island, made up of a ring of reef and coral islets, built on a thick layer of dead coral. The flaky soils of these islands are not engulfed by the waves as the living corals shield them from erosion.

Atolls are the islands most at risk from the effects of climate change. The degradation of the corals as a result of bleaching and acidification could destroy the physical barrier which shelters these islands from heavy ocean swell. Atolls are made of coral; if the latter disappear, these islands too will be condemned to vanish. Furthermore, rising sea levels are likely to accelerate the deterioration of these islands. Atolls never rise more than 2 or 3 metres above sea level. They are therefore particularly vulnerable to both temporary and permanent changes in sea level. If the rise is gradual, healthy corals could continue to grow and possibly follow the water level, but degraded corals would be incapable of doing so.

With 84 atolls, Polynesia is home to 20% of the world's atolls. The human populations who inhabit these islands are at risk from climate change. They could be forced leave their atolls and seek

luthor522

Fakarava atoll in Tuamotus

refuge on higher islands or continents. In the neighbouring islands of Tuvalu, there is already talk of "climate refugees". Since 1993 these islands have experienced a rise in sea levels of approximately 2 millimetres a year, caused by the El Niño weather system (Church, 2006; IPCC 2007). They have lost 3 metres of beach front, their crops are inundated for five months of the year, and salt water has seeped into the water tables. The impact of tropical storms on the coast is becoming more and more violent, and whole populations have already had to be temporarily evacuated from their islands during very high tides.

degradation of the ecosystemic equilibrium. These changes will take place to the detriment of the fragile indigenous species and will likely lead to the expansion of invasive species into hitherto uninfested areas. The Euglandina carnivore snail, for example, cannot develop above a certain altitude (about 1,400 metres). This threshold is likely to rise with increasing temperatures. The upward migration of invasive species towards higher altitudes will have a major impact on the indigenous fauna and flora; especially on the remarkable French Polynesian malacofauna which is mostly limited to the last remaining zones of preserved mountain forests (see Box 4.3).

Box 4.2: Subalpine Forests of French Polynesia: Precious and Threatened Ecosystems

Tahiti is the only island in the South Pacific to possess tropical subalpine forests. These habitats are limited to three summits above 2,000 metres and do not exceed a total area of 125 hectares. Subalpine zones are characterized by extreme climatic conditions, with low average temperatures (<14°C), a wide range of temperature variations, and inferior rates of rainfall than lower altitude mountain zones. The characteristic vegetation of these ecosystems, known as orophile or mountain vegetation is very rigid with small, tough leaves. Almost entirely devoid of direct human-induced degradation, subalpine forests are of tremendous biological importance. Inaccessibility and climate have limited the destruction of these habitats and the spread of the many of the invasive species found at sea level. These habitats therefore have a remarkable flora and fauna, which are rich in endemic species. However, these subalpine regions are also vulnerable to a rise in temperatures. A recent study has shown that an average rise in global temperatures of 3°C between now and the end of the century would destroy 80% of alpine havens, and lead to the disappearance of one-third to one-half of all alpine plants in the world (Halloy and Mark, 2003).


Marie Fourdigniez

Subalpine forest in Pito Hiti, Tahiti

A project for the long-term monitoring of the composition and functioning of Tahiti's subalpine vegetation is currently being carried out by the Research Delegation of the Territory. An inventory of subalpine flora, to be undertaken every 5 to 10 years, will allow accurate appraisal of the impacts of climate change on these forests. It will also enable potential changes in the ecosystem to be accurately observed. Potential modifications include changes in the spatial distribution of mountain flora, changes in seasonal behaviour, and new invasions by alien species, or even the complete extinction of indigenous species (Meyer and Taputuarai, 2006).

Box 4.3: Endemic Snails and Climatic Variations

Terrestrial gastropods are one of the jewels of Polynesian fauna. More than 320 species were inventoried and 100% of native species are endemic (Gargominy, 2003). These species are of major interest for the general study of natural evolution and speciation (evolutionary process through which new species develop). However, most of these species are under severe threat (IUCN Red List), especially from a predatory snail introduced from Florida (*Euglandina rosea*). The latter was originally introduced to combat *Achatina fulica*, another species of invasive snail which was wreaking devastation among local crops. The Euglandina has already caused the extinction of 57 endemic species of the *Partula family*, including all the species from the Island of Moorea (Pointier and Blanc, 1985).


Olivier Gargominy

Predator snail (*Euglandina rosea*) feeding on an endemic snail species

The remaining species of French Polynesian snails are now mostly confined to high altitude areas where neither *Euglandina*, whose altitudinal threshold is believed to be between 1,300 and 1,500 metres (Gerlach, 1994), nor the invasive Miconia plant, which does not grow above 1,400 metres, have been able to evolve. As a result, the spatial distribution of indigenous French Polynesian gastropods is extremely limited. For instance, the main populations of some snail species are confined to an area of less than 2 km² (Gargominy, personal communication). An increase in temperatures brought about by climate change could critically endanger the last remnants of endemic species. Rising isotherms would both decrease the gastropods' area of occupancy and lead to the upward migration of the predatory snail towards higher altitudes (Gargominy, 2008).

Box 4.4: Pearl Farming: A Delicate Process

In French Polynesia more than 7,000 people depend directly upon the production and sale of Pacific black pearls for their livelihoods. This market accounts for 80% of the territory's exports. This delicate pearl, produced mainly in the atolls of the Tuamotus Islands, requires very specific temperature and water-quality conditions. By increasing the temperature and the acidity of the ocean, climate change could have serious consequences for pearl production in Polynesia. The actual impact of climate change on pearl farming in the region is still largely unknown; however several studies have confirmed the existence of potential impacts. In 2000, the Cook Islands in New Zealand experienced exceptionally dry conditions, with an absence of wind and important increases in temperature. These conditions reduced the level of oxygen in the lagoons and led to an increase in diseases affecting oysters; the result was massive mortality among the pearl-producing oysters. The resulting economic losses for the region have been estimated at Euros 22 millions in loss revenue. The oysters could also be vulnerable to increasing acidification of the oceans, caused by a rise in the concentration of CO_2 in the water. It has been demonstrated that calcification of the Pacific Oyster (*Crassostera gigas*) diminishes in direct proportion to the increase in the acidity of the sea water (Gazeau et al., 2007).

Mila Zinkova

Black Pearl and its shell

tpsi

Pearl farm in Fakarava, Tuamotus

Box 4.5: Ciguatera: Coral Degradation-Related Food Poisoning

Ciguatera is a common form of food poisoning in tropical regions. It is caused by the ingestion of lagoon fish infected by dinoflagellates – photosynthetic micro-algae that form on coral debris. These dinoflagellates produce powerful neurotoxins, which accumulate in herbivorous marine animals and are subsequently transmitted up the food chain by carnivorous fish (Bagnis, 1992). Dinofalgellates occur naturally on coral reefs but become a problem when their density hits critical levels. Ciguatera is caused by the ingestion of a large quantity of these neurotoxins. It is often referred to in the Pacific as the "itching illness" because it causes serious bouts of itching. Throughout French Polynesia there are on average 800 to 1,000 cases of the disease per year (ONERC 2006). A high rate of mortality among the corals caused by bleaching could lead to a spread of ciguatera (Kohler, 1992). The surface of dead corals is an ideal breeding ground for algae and thus for the proliferation of related epiphytes like dinoflagellates (Quod, personal communication). Greater studies are however needed in French Polynesia and elsewhere to establish with certainty the link between coral bleaching and an increase in ciguatera.

Grant Hutchinson

Bleached corals are ideal substrates for ciguatera development.

Socio-economic implications

A large majority of the population of French Polynesia lives in the narrow coastal strips. A rise in sea levels could therefore have disastrous consequences on these urban settlements and hence on the economy of the territory. A simulation of rising sea levels carried out on the site of Tahiti international airport illustrated their potential impacts. Tahiti airport, like many in French Polynesia, has been built on a coral reef. A rise of 88 centimetres in the sea's level (the top end of IPCC projections) would result in the complete submersion of the airport and of part of the surrounding town of Faaa where it is situated. The economic impacts would be very serious for the territory; degradation of the beaches and coral reefs would impact upon the tourist industry which is largely dependent on these natural resources. Pearl farming, a very delicate process with a high value added, would also be disrupted by a change in the environment (see Box 4.4). Finally, climate change presents a risk to public health in Polynesia, through, for instance, a rise in the number of vector-borne infectious diseases such a dengue fever (see Box 2.5), or the proliferation of the micro-algae responsible for ciguatera, food poisoning caused by ingesting infected fish (see Box 4.5).

Responses to climate change

Box 4.6: Moorea Island: A Model Ecosystem for Global Change Science

The island of Moorea, embedded in the natural laboratory of French Polynesia, is emerging as a model ecosystem to understand ecological processes in the context of local and global change. The "Moorea Ecostation" unites the Centre de Recherches Insulaires et Observatoire de l'Environnement (CRIOBE; EPHE-CNRS) and the Richard B. Gump South Pacific Research Station (UC Berkeley) in collaboration with French Polynesia. Inspired by the model organism approach of molecular biology, an international consortium recently launched the ambitious "Moorea Biocode Project" (MBP) to genetically "barcode" every non-microbial species on Moorea. Aimed at stimulating a revolution in ecology for the benefit of conservation, the MBP will sample from the coral reef to the mountaintops to produce a verifiable (vouchered) "All Taxa Biotic Inventory" (ATBI) of the entire ecosystem by 2010. It will also help build the informatics services needed for ATBI and biocode-enabled research in other model ecosystems. During a pilot project in 2006, the team already identified and sequenced most of Moorea's fish (457 species inventoried to date) and made a start on the rich marine invertebrate fauna (>1,000 sampled so far) as well as terrestrial insects, lizards, and ferns (Davies, 2008).

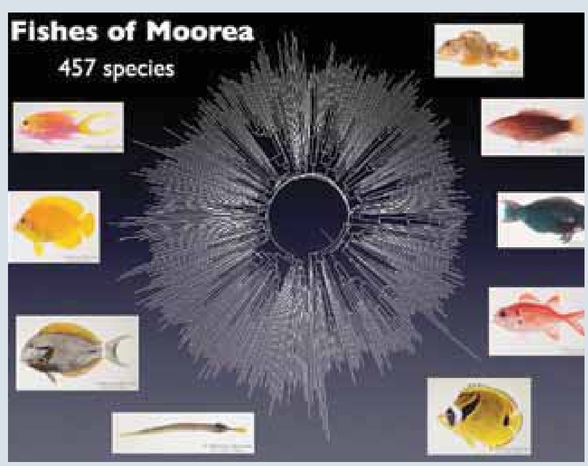
Jérôme Petit

Insect collected in Moorea

The goal of Biocode, in Moorea and eventually in other model ecosystems, is to provide new tools for understanding fundamental ecological processes using a whole-system approach. The resulting genetic observatories will enable scientists to better quantify the impacts of global change. Model ecosystems should also bridge research and management, stimulating innovative new practical solutions for conservation and providing powerful learning laboratories for sustainable development.

Jérôme Petit

Entomologist team of the Biocode project

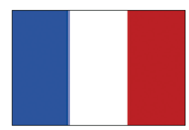


Chris Meyer

Pylogenetic tree of the fish species collected in Moorea

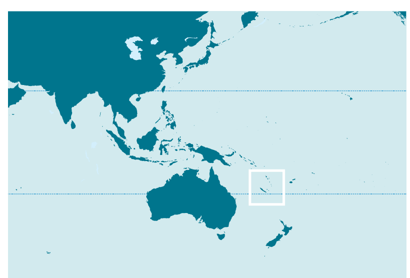
Thibaud Debrosses

New Caledonia



4.3 New Caledonia (France) OCT

Number of islands:	1 main island and 4 groups of secondary islands
Population:	224 824 inhabitant (2008)
Area:	18 575 km²
Population density:	12,1 inhabitant / km²
GDP/inhabitant:	12 000 €/ inhabitant
Unemployment rate:	17,1% (2004)
Economic activities:	Nickel mining, tourism



New Caledonia is a French overseas territory situated in Melanesia, 1,500 kilometres to the east of Australia and 2,000 kilometres to the north of New Zealand. The territory consists of one main island, Grande Terre, and several groups of secondary islands, including the Belep archipelago to the north, the Isle of Pines to the south, the Loyalty Islands to the east and the Chesterfield Islands a little further away. Grande Terre, the Mainland, is over 400 kilometres long and 50 to 60 kilometres wide. The highest point on the island is Mount Panié which rises to an altitude of 1,628 metres. New Caledonia's exclusive economic zone (EEZ) extends over an area of 1,740,000 km². The territory's population density is particularly low (12.1 inhabitants per km²), and unevenly distributed: 69% of inhabitants live in the Southern Province and 40% in the capital, Nouméa. The territory contains close to 25% of known global nickel reserves. Nickel mining is the main pillar of the island's economy; it accounts for 90% of export revenues. Other economic sectors include tourism (some 100,000 visitors come to the island each year), an as yet relatively little developed industry but considered to be a very important future driver of the economy. Financial assistance from France still accounts for 35% of GDP. Agriculture and livestock are poorly developed and have declined steadily over the last few years. However, subsistence agriculture and fishing for personal comsumption still occupy an important place in the Caledonian economy. A referendum on New Caledonian independence is planned for 2014.

4.3.1 Current state of biodiversity

New Caledonia is home to an extremely rich terrestrial and marine biodiversity. It has one of the highest observed rates of endemism in the world for terrestrial flora. The territory is a global biodiversity hotspot (Myers, 2000). It is the smallest single biodiversity hotspot in the world.

Terrestrial biodiversity

The east coast of New Caledonia, which is exposed to prevailing winds, is characterized by tropical humid landscapes. The dense humid rainforest covers 21% of the territory and still occupies a single block of thousands of hectares. Conversely, the west coast, which is sheltered from the wind by a central mountain chain, was once covered by dry forest. Today, the landscape is covered by herbaceous vegetation and savannahs. This secondarized area is home to the Melaleuca (*Melaleuca quinquenervia*), a species of myrtle and a symbol of the territory. Subsistence agriculture is practised on 40% of the territory. New Caledonia displays remarkable plant diversity. There are 3,261 species of indigenous flora (74% of which are strictly endemic), almost as many as on the whole of continental Europe (3,500 species). New Caledonia is also host to 106 species of endemic reptile, including the world's largest gecko (*Rhacodactylus leachianus*), as well as six species of endemic bat and 4,500 species of invertebrates, of which 90% are endemic. The bird life of New Caledonia includes 23 species of endemic birds, among then the Kagu (*Rhynochetos jubatus*), an iconic crested bird and the last remaining survivor of the species family, and the Giant imperial pigeon (*Ducla goliath*), the largest arboreal pigeon in the world.

djringer

The Cagou (*Rhynochetos jubatus*) is an emblematic bird from New Caledonia

Marine biodiversity

New Caledonia's barrier reef is 1,600 kilometres long, making it the second longest barrier reef in the world after the Australian Great Barrier Reef. This reef surrounds a vast lagoon of some 23,400 km² and contains 14 280 km² of reef. Seagrass beds occupy almost a third of the lagoon. Despite their size, the New Caledonian reefs remain relatively unexplored. A recent inventory of the overall marine biodiversity of New Caledonia identified approximately 15,000 species, including 1,950 species of fish, 5,500 species of molluscs, 5,000 crustaceans,

Brewbooks

The New Caledonian reef is 1,600 kilometers long

600 sponges and 300 corals (Spalding, 2001). The average endemism is about 5%, much lower than that of terrestrial biodiversity. The territory, which is a sanctuary for cetaceans, plays host to a dozen species of marine mammals including the Dugong (*Dugong dugon*), an iconic and endangered species. The territory is an important nesting site for three species of marine turtle, the Green turtle (*Chelonia mydas*), the Hawksbill turtle (*Eretmochelys imbricata*) and the Loggerhead turtle (*Caretta caretta*). Mangroves cover between 150 and 200 km². They are seriously degraded in the Nouméa region. There are 37,500 hectares of protected areas – about 2% of the surface of the lagoon – including 13 marine protected areas (MEDAD 2004).

Current threats

New Caledonia experienced massive deforestation during the 19th century, due to wood production, agriculture, livestock rearing and poorly managed bush fires. Today, only 1% of the original surface area of dry forest remains on the west of the island. It is highly threatened (see Box 4.8). The rain forest on the east of the island once covered 70% of the territory; today it only covers 21% (Gargominy 2003). Fires destroy thousands of hectares of forest every year. Compounding this threat is increasing pressure from invasive species such as deer, pigs, dogs, rats and even the Little fire ant (*Wasmania auropunctata*), which exert considerable pressure on the local flora and fauna. Similarly, invasive plant species such as the Lantana camara and the Guava (*Psidium guajava*) are strangling the indigenous flora. Bush fires and over-grazing are causing the erosion of the hillsides and land-based sedimentation, which are

Henri Blaffart

The Rusa Deer (*Cervus timorensis russa*), introduced to Grand-Terre in 1870, is a big pressure for the endemic vegetation


Régis Dick

Nickel mining activities cause important sedimentation of the lagoon

damaging the reefs. In an era of increasing tropical storms, this phenomenon is the foremost cause of coastal, fringe reef and lagoon deterioration, particularly on the east coast. Furthermore, the erosion is exacerbated by mining activities in the nickel-rich zones. A study of erosion around one of the hillsides (Ouenghi) was carried out by the IRD in 1991. Over a period of 28 years, natural erosion and mining have led to the dumping of a solid mass of some 1,000,000 m3. A 3-kilometre wide delta has advanced 300 to 400 metres over the lagoon (Danloux, 1991). Nickel mining is a politically sensitive subject; while it generates pollution and causes important sedimentation of the lagoon, it remains the most important economic sector on the island.

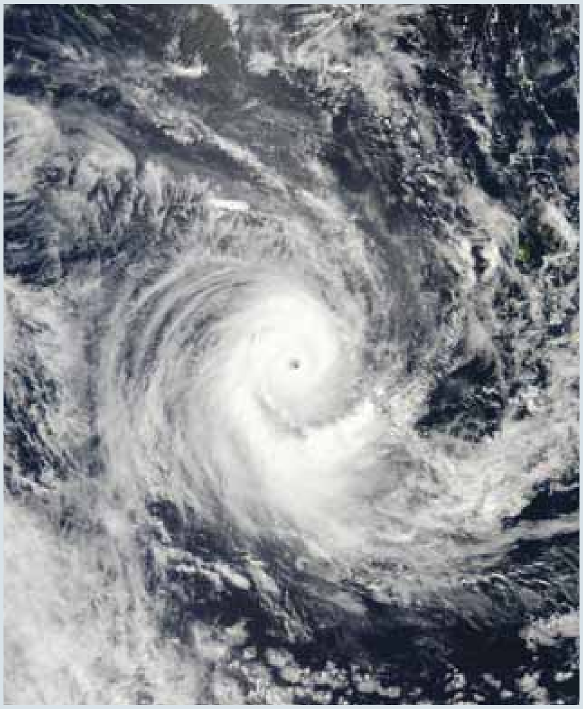
4.3.2 New threats resulting from climate change

Impacts on biodiversity

Current data about the potential or observed impacts of climate change in New Caledonia are very limited. The foremost impact on the marine environment is without doubt the degradation of the coral reefs as a result of successive bleaching events. Between January and March 1996, following unusually warm water temperatures, the corals of New Caledonia suffered a bleaching episode. Around Nouméa, the rate of coral mortality was as high as 80%,

Box 4.7: Impact of Tropical Storms on the Reefs: The Case of Hurricane Erica in New Caledonia

On 14 March 2003, hurricane Erica, a Category 5 storm, battered the marine park in the south of New Caledonia. A hurricane of such intensity is unusual in the region. The park's corals were studied in nine different observation stations a few days before the storm (8-11 March 2003), a few days after the storm (23 March -15 April 2003), and, finally, 20 months later (14-16 November 2004). The hurricane had a significant impact on the reef formations and the fish populations in the park. The fragile coral formations (the branching, tubular and foliose corals) diminished significantly, resulting in a loss of habitat for the fish populations. The wealth of commercially-exploited fish and butterfly fish was seriously affected by Erica's passage. Twenty months after the hurricane, the reefs had not regenerated; the broken corals had turned into debris and were being colonized by algae. The medium-term impacts of the hurricane turned out to be even more damaging than the short-term impacts. Twenty months after the storm, the richness and density of the fish were even lower than before the storm, and lower still than those recorded a few days after the storm. Furthermore, a different species composition was observed in the medium term. Herbivorous fish, associated with debris and benthic species that feed on micro-invertebrates, had replaced the fish usually associated with corals. The corals of New Caledonia are not adapted to tropical storms of such intensity; the immediate impacts of these events on the reefs are very serious and profoundly degrade the reefs in the short and medium term. Intensification of tropical storms in the region, as predicted by the IPCC, could irreversibly modify the coral formations and the species' composition of New Caledonia (Wantiez, 2005).


Nasa's Visible Earth

Hurricane Erica

reaching as high as 90% on some shallow reefs (Richer de Forges and Garrigue, 1997). However, the affected areas were very limited in size. The coral reefs were also damaged by the tropical storms which battered the territory. The impact of hurricane Erica in 2003 on the reefs and the fish population has been accurately measured (see Box 4.7). An increase in the intensity of such extreme weather events is likely to hasten the degradation of the reefs. Another study has demonstrated that a warmer and more humid climate, with an increase in levels of precipitation and runoff, could affect the size of the reef fish (Wantiez, 1996). Indeed, the leaching of soil nutrients as they are carried towards the lagoon increases the turbidity of the water, thereby reducing the amount of light entering the water and changing the habitat structure and food resources of the reef fish.

At the same time, a rise in sea levels threatens the beaches and coastal ecosystems of New Caledonia. Estuaries and low-lying islands are likely to be particularly affected, especially during tropical storms. The Island of Ouvéa seems to be the most threatened, along with some coastal plains and mangrove-lined estuaries on the west coast. The degradation of the beaches could also perturb the turtle populations that depend upon these habitats for their reproduction. There are no observations or projections of the impacts of climate change on terrestrial ecosystems. However, several experts consulted cited potential impacts on the already seriously degraded dry forests (see Box 4.8). The high level of species endemism in New Caledonia is the result of strong speciation caused by the evolution of species in environments or ecosystems with a limited surface area. A change in climate, even minimal, could affect the micro-climatic conditions in these environments and imperil the survival of the ecosystems (freshwater ecosystems, high altitude forests, etc.). The functioning of the wetlands in the south (lakes region) is as yet poorly known but a change in rainfall levels could influence these environments and their associated fauna and flora (Goarant, personal communication).

Box 4.8: Dry Forests of New Caledonia Threatened by Fire

Once upon a time, the dry forests of New Caledonia covered the entire west coast of the island up to an altitude of 300 metres, or about one-quarter of the territory. Today, only a few dispersed fragments of these habitats remain (253 in total); their total area is 50 km², or 1% of their original area (Papineau, personal communication). These last remaining vestiges of dry forest are a conservation priority. They are home to 262 species of endemic plants, of which about 60 are only found in these habitats. These are species that are particularly well adapted to the dry conditions, such as, for example, the dry forest Gardenia (Gardenia urvillei). These forests are also home to specialized fauna including reptiles, birds and invertebrates, and 33 species of butterfly that occur only in these ecosystems. The already severely degraded dry forests have a very limited resilience in the face of the pressures with which they are currently confronted. They are further threatened by human impacts such as bush fires, invasive species (deer and wild pigs) and extensive cattle farming. Climate change will likely further diminish the resilience of these habitats. There are no observation data or projections about the impacts of climate change on these ecosystems, but the experts consulted put forward certain hypotheses. The longer and warmer dry seasons predicted, are likely to increase the incidence and spread of fires. Similarly, some plant species will likely be affected by repeated periods of drought, leading to change in their fructification patterns and limited growth (Papineau, personal communication). Since 2001 a programme to conserve these ecosystems has been led by the region in close collaboration with several partners (French State, WWF, IRD, Conservation International, etc.). Some of the activities being carried out under this programme include ecosystem mapping, inventorying of flora and fauna, protection, restoration, and awareness raising activities (www.foretseche.nc).

C. Pauellabauer

Dry forests in New Caledonia cover only 1% of their original distribution

Box 4.9: Impact of Rising Sea Levels on Mangroves in the Pacific

Mangroves have a very high ecological, cultural and economic value. They provide indispensable nurseries for fish (see Box 2.5), filter coastal pollution and provide wood for local populations. Some 20% of the global area of mangrove coverage has been destroyed since 1980, largely on account of deforestation, construction of infrastructure or development of aquaculture (FAO, 2008). Rising sea levels resulting from climate change represent a new threat to mangroves in part because of the direct stress caused by submersion, but also because of increasing salinity.

A recent study conducted by UNEP modelled the vulnerability of indigenous mangroves in 16 Pacific island states and territories (including New Caledonia) in the face of potential increases in sea level. Most of the islands studied have already had to deal with significant increases in water levels, resulting from an average rise of 2 millimetres per year over the last few decades. Between now and the end of the century, if sea levels rise by 88 centimetres (the worst-case scenario proposed by the IPCC), UNEP models foresee the potential disappearance of 13% of the mangroves throughout the 16 Pacific islands studied (UNEP, 2006). According to this same scenario, New Caledonia could lose up to 3,000 hectares of mangroves (or 14% of the existing 20,250 hectares). That said, these estimates need to be fine-tuned because rises in sea levels are unlikely to be uniform but rather will vary depending on the region. New Caledonia in particular has experienced very limited increases over the last few decades (0.2 millimetres per year only), while other territories, like the Solomon Islands for example, have even experienced a drop in sea levels (UNEP, 2006).


Christophe laïchouchen

Mangrove in New Caledonia

Socio-economic implications

Repeated droughts caused by climate change could damage subsistence agriculture and livestock farming, which still play an important role in New Caledonia. The resulting deficits could force the populations to purchase certain foodstuffs, which would lead to a drop in the standard of living (Blaffart, personal communication). Some agricultural production will be more affected than others. Litchis and mangoes are difficult to grow in the absence of a cool season. Subsistence fishing also plays an important role in the territory's economy. A reduction in fish stocks, caused by the degradation of the reefs, will have a non negligible impact on this sector. Variations in temperature and precipitation could also have an impact on public health by facilitating the spread of certain vector-borne diseases such as dengue fever or malaria (see Box 2.5). Malaria is currently absent from New Caledonia, but present in Vanuatu. With a rise in temperatures, the risk of this disease being introduced would increase (Goarant, personal communication). Finally, a large majority of the inhabitants of New Caledonia lives along the coast. Low-lying urban areas are highly vulnerable to rising sea levels.

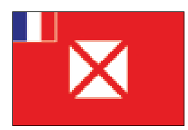
Responses to climate change

Box 4.10: Reef Check: A Global Database on the State of the World's Coral Reefs

Reef Check is a rapid standardized protocol to evaluate coral reefs. It was devised primarily for use by non-professionals and volunteers. Launched in 1997, it has been implemented worldwide and involves a large network of independent volunteer divers. Regional, national and local coordinators put non-professional diving teams in contact with professional marine scientists. The scientists are responsible for training volunteers to collect precise data. Reef Check uses carefully chosen bio-indicator organisms selected on the recommendation of the Global Coral Reef Monitoring Network (GCRMN). The methodology, which can be learned in one day, involves a very strict system for guaranteeing the quality of the observations (Westmacott et al., 2000). This protocol has been implemented in more than 80 countries worldwide and, in particular, in most of those overseas territories of the European Union which are home to reefs. Reef Check allows a fairly comprehensive monitoring of the state of the world's coral reefs and highlights the greatest global threats to coral reefs such as the impacts of climate change. In 2002, Reef Check published a report based on five years of monitoring activities entitled "The Global Coral Reef Crisis: Trends and Solutions". This report concluded that there is not a single coral reef in the world that has been spared from the impacts of human activities like over-fishing, pollution or climate change. In New Caledonia, the Reef Check protocol has been applied to 51 monitoring sites by the territory's provinces and several local diving clubs. The data collected will subsequently by centralized by IFRECOR (the French coral reef initiative).

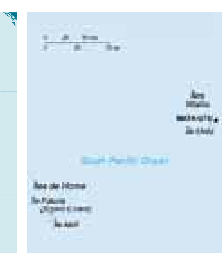
Xavier Pinaud

Wallis and Futuna



4.4 Wallis and Futuna (France) OCT

Number of islands:	3 main islands and several islets
Population:	16 448 inhabitants (2008)
Area:	142 km²
Population density:	115 inhabitants / km²
GDP/inhabitant:	2 000 €/ inhabitants (2004)
Unemployment rate:	n/a
Economic activities:	Agriculture and livestock



Wallis and Futuna is a French overseas territory situated mid-way between New Caledonia and Tahiti. It consists of two distinct archipelagos, 230 kilometres apart: the Wallis archipelago, whose central island is Uvea (78 km²) and the Horn archipelago, made up of the Islands of Futuna (46 km²) and Alofi (18 km²). Uvea is a low-lying island with a single cliff, Lulu Faka, which rises to 151 metres. Futuna, on the other hand, has steep slopes and high mountains, including Mount Puke (524 metres). The territory's exclusive economic zone extends over 266,000 km². The economy of Wallis and Futuna is mainly based on agriculture and livestock rearing for local consumption. For the most part, the inhabitants of the island do not have access to the monetary economy. Close to 70% of those who are employed, work for the local public administration. Tourism is largely undeveloped, like the private sector, which employs about 1,000 people in the retailing sector, the mother-of-pearl craft industry and lagoon fishing.

4.4.1 Current state of biodiversity

Remarkable habitats and species

Xavier Pinaud

Coral reefs of the territory are largely unexplored

Wallis and Futuna's biodiversity is relatively limited. This is because these islands are geologically very young (2 million years) and have a limited surface. Tropical forests once covered practically all the islands; today they cover a little less than 10% of the surface (Meyer, personal communication). There are only a few remaining strips of forest in Wallis. Today, the island's coverage consists for the most part of more or less degraded secondary forest (bushy thickets) made up of moors of Dicranopteris (fork fern) called toafa, and cultivated and fallow land. The territory is home to 350 species of vascular plants of which only seven are endemic. The bird life is relatively poor with 25 nesting species, 15 of them terrestrial and 10 of them marine species. Wallis has a barrier reef 63 km² long and a lagoon of 200 km². Futuna and Alofi have no lagoon, but an apron reef some 100 metres wide on average. The territory has 52 types of coral, 648 species of fish and 310 species of molluscs (Gargominy, 2003). The coral reefs of the territory are largely unexplored.

Current threats

The territory's foremost environmental problems are erosion and loss of soil fertility in Futuna, resulting from slash-and-burn agriculture. Small-holder farmers burn their fields after the harvest thereby contributing to the disappearance of the top soil. The nutrients and organic matter contained on the sloping hillsides of the island are carried off to the sea (this is especially true of Futuna) and the resulting sedimentation leads to important degradation of the reefs. Turbidity and eutrophication caused by erosion are among the causes of this degradation. Some traditional fishing methods too are destructive for the marine environment. Added to this is the over-exploitation of fish stocks in certain areas (Salvat, personal communication).

Nicolas Ferraton

Coconut trees degradation with erosion in Wallis

4.4.2 New threats resulting from climate change

Impacts on biodiversity

The most serious effect of climate change on the biodiversity of Wallis and Futuna is probably coral bleaching caused by rising water temperatures. The magnitude of the bleaching is difficult to gauge as the territory's reefs have not been widely studied. They have only been monitored since 1999. Significant coral bleaching was observed to a depth of 20 metres in 2003, but no evaluation of the mortality rate was carried out (Vieux, 2004). A rise in sea level could affect the mangroves and the coastal ecosystems of the territory. The first signs of coastal erosion were observed in Wallis with the disappearance of a number of beaches and the uprooting of coconut trees. That said, however, it is difficult to state with certainty that there is a link between these isolated cases of erosion and rising sea levels. These incidents of erosion could equally be the result of the suppression of the mangroves, the extraction of sand by the local population, or changes in sea currents. The projected increase in sea levels could also impact upon the wetland areas of the territory. A rise in the water level in the aquifers could reduce the fresh water supply in the water table. This would in all likelihood lead to changes in the distribution of vegetation throughout the territory (similar to those observed on the Islands of Tuvalu) (Ferraton, personal communication). Indeed, a number of plants obtain their water directly from the water table.

Box 4.11: Potential Submersion of the Coastal Areas of Wallis and Futuna

The IPCC estimates that there will be a rise in the global sea level of between 0.23 and 0.47 metres between now and the end of the century (this projection does not include the potential sea level rise generated by ice melt). Projections for Wallis and Futuna are similar. Some low-altitude coastal zones are likely to suffer serious erosion, temporary flooding in the event of tropical storms, and in some cases, permanent submersion. An exercise in modelling to illustrate the potential submersion of the Island of Uvea was carried out by the Territorial Services for Rural Affairs and Fishing (STARP); it used a range from 0.5 to 3 metres. This study showed that several hundred seaside homes in Uvea would be at threat from a rise in the sea level of only 0.5 metres. Several measures have been implemented at a local level to combat erosion: shoring up the sea front (Vaitapu), construction of protection walls (Gahi Bay), natural shoring using building debris (Liku), and planting hedges of vetiver grass (Vaitapu) (photos). While these initiatives help to limit coastal erosion on a local and temporary basis, they will not provide long-term protection against a significant rise in sea levels. The potential submersion of urban areas would seriously affect the economy of the territory, and lead to the displacement the population towards the interior and towards the last remaining natural areas on these islands.

N. Ferraton

Circulation of fresh water on a traditional taro flooded plantation

Socio-economic implications

A rise in the sea level around Wallis and Futuna could lead to the submersion of certain inhabited coastal areas. Topographic modelling carried out by the Territorial Services for Rural Affairs and Fishing (STARP), allows a visualization of the partially submerged land areas (Box 4.11). A rise in sea level could also have an impact on agriculture, particularly the Taro plantations, situated in the wetlands back from the coastal areas (Box 4.12). Finally, salt water infiltration into the water table is likely to put greater pressure on Wallis and Futuna's already limited freshwater supplies, and to affect the local population.

Box 4.12: Climate Change and Agriculture: The Case of the Wallis and Futuna Taro Plantations

Subsistence agriculture plays an important role in the economy of Wallis and Futuna. Taro, in particular (*Colocasia esculenta*), a starch-rich root plant, is widely grown on the territory for local consumption. This plant is cultivated in "taro beds", a very elaborate method of cultivation carried out in the flood plains immediately behind the coastal banks. It is in these areas, where the water table skims the land's surface, that taro clippings are planted in small clumps of soil. Large trenches of some 2 to 4 metres deep are then dug around these clumps. These are then filled by the water table. A canal is dug to allow the water from the water table to flow out to the sea. Over the last few years some farmers in Wallis have noticed an incursion of sea water into the taro plantations during very high tides. Sometimes, dams have even been built to prevent this from happening (photo). Saline infiltration seriously impacts upon the taro crops; it can completely destroy them if the levels of salinity are too high. There have been no accurate assessments of salt water infiltration, and the link with climate change remains to be scientifically proven. However, first observations show that a significant rise in sea level could seriously affect the traditional cultivation of taro in Wallis and Futuna.


N. Ferraton

Shoring up the sea front (Vaitapu)


N. Ferraton

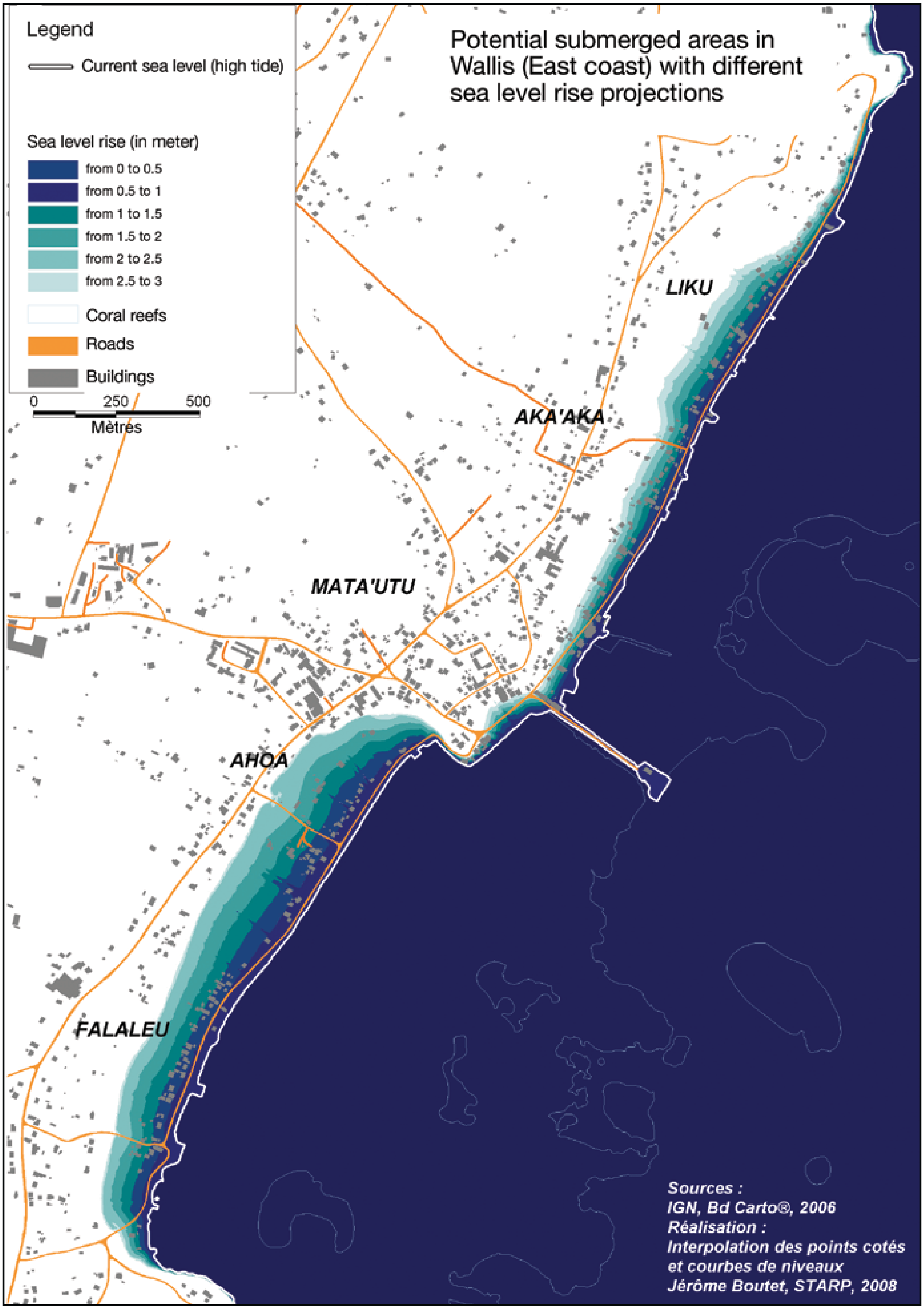
Protection wall (Gahi Bay)


N. Ferraton

Shoring using building debris (Liku)


N. Ferraton

Hedges of vetiver grass (Vaitapu)


Potential submerged areas in Wallis (East coast) with different sea level rise projections
Legend
Current sea level (high tide)
Sea level rise (in meter)
from 0 to 0.5
from 0.5 to 1
from 1 to 1.5
from 1.5 to 2
from 2 to 2.5
from 2.5 to 3
Coral reefs
Roads
Buildings
0
250
500
Mètres
LIKU
AKA'AKA
MATA'UTU
AHOA
FALALEU
Sources :
IGN, Bd Carto®, 2006
Réalisation :
Interpolation des points cotés
et courbes de niveaux
Jérôme Boutet, STARP, 2008

Snuva

Pitcairn

4.5 Pitcairn (United Kingdom) OCT

Number of islands:	4 islands
Population:	47 inhabitant (2008)
Area:	62 km²
Population density:	<1 inhabitant/km²
GDP/inhabitant:	n/a
Unemployment rate:	n/a
Economic activities:	Subsistence fishing and agriculture

Pitcairn is the last remaining British territory in the Pacific Ocean. It consists of four islands with a total surface area of 47 km², situated 2,200 kilometres to the east of Tahiti. The only inhabited island, Pitcairn, is home to a population of about 50, which makes it the smallest – in terms of population – political entity in the world. Most of the inhabitants are the descendents of the famous Bounty Mutineers and their Tahitian wives, who took refuge on Pitcairn in 1790. Pitcairn's exclusive economic zone extends over 560,000 km². The island's economy is dependent on subsistence agriculture and fishing.

4.5.1 Current state of biodiversity

Remarkable species and habitats

The island of Pitcairn is a small volcanic island of only 5 km². The flora of this island includes 80 species of indigenous vascular plants, of which only 10 are endemic. Henderson Island, a UNESCO World Heritage site, is a raised coral island of about 37 km². The islands of Oeno and Ducie are small atolls. The territory is home to 28 species of nesting bird, most of which are seabirds. Approximately 90% of the global population of Murphy's petrel (*Pterodroma ultima*) nest on the island of Ducie (Sanders, 2006). A population of Green turtles uses East Beach on the Island of Henderson as a breeding ground (www.wetland.org). The coral reefs are well developed in Oeno and Ducie. Two-thirds of Henderson Island are surrounded by coral reef. However, the reefs around Pitcairn are only slightly developed (Hepburn, 1992). On the whole, Pitcairn's biodiversity has been little documented.

Current threats

NASA

Hendersen island is a raised coral island located 193 km from Pitcairn

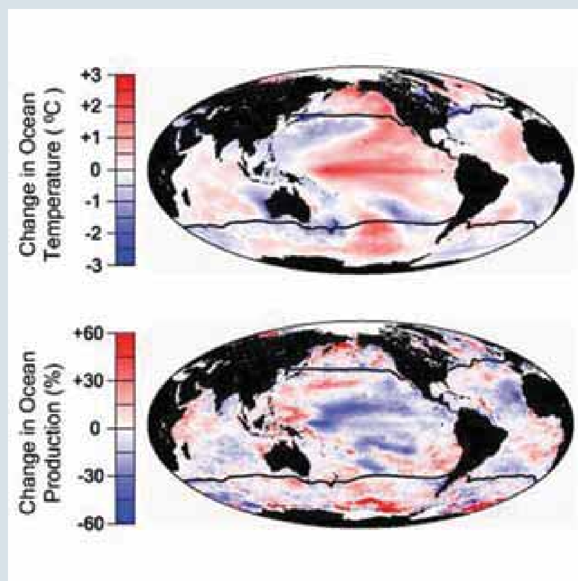
On Pitcairn, the introduction of invasive species has damaged the natural environment, feral goats, for example, have seriously affected the local habitat. Much of the local woods, used for fuel, building and carving for export have also been over-exploited. Henderson remains little disturbed; because of its remoteness and inhospitable nature, it has suffered relatively little human influence.

4.5.2 New threats resulting from climate change

There are no specific scientific data on the impacts of climate change on the biodiversity of Pitcairn. However, it is possible to hypothesize that the corals of Oeno and Ducie will in all likelihood be affected by rising sea temperatures and the resulting bleaching episodes. A rise in sea levels could also affect the coastal areas of these coral islands and indirectly threaten the bird and turtle populations that inhabit them.

Box 4.13: Warmer Oceans Produce Less Phytoplankton

An American team has used satellite imagery to quantify the concentration of chlorophyll (and hence phytoplankton) in the oceans over the last 10 years by analysing the different levels of pigment in the surface layer of the ocean. The results have shown that the quantity of phytoplankton has significantly declined and that this decline has been in direct proportion to the rise in water temperatures and the corresponding slow-down of the convectional ocean currents. The deep water cold currents bring to the surface the mineral salts necessary for the development of plant-based plankton. The warming surface waters prevent the deep water currents from rising to the surface, thereby decreasing the supply of nutrients required for phytoplankton growth. Phytoplankton have declined by as much as 30% in some areas during the last 10 years, due to temperature rises attributed to ENSO (El Nino Southern Oscillation) cycle. This has significant consequences for the entire marine food chain as well as considerable impacts on the global carbon cycle. Scientists estimate that because of this decline 190 million tonnes of carbon per year have not been converted to organic matter (Behrenfeld, 2006). This reversal of the ocean currents could speed up the release of CO_2 into the atmosphere. Thus, there is a fundamental relationship between water temperature and phytoplankton. When waters warm, productivity goes down. As human-induced changes in climate cause warming beyond natural fluctuations, ocean phytoplankton production will probably go down.



Behrenfeld 2006

Variations in the ocean temperature and the ocean phytoplankton production over the last 10 years

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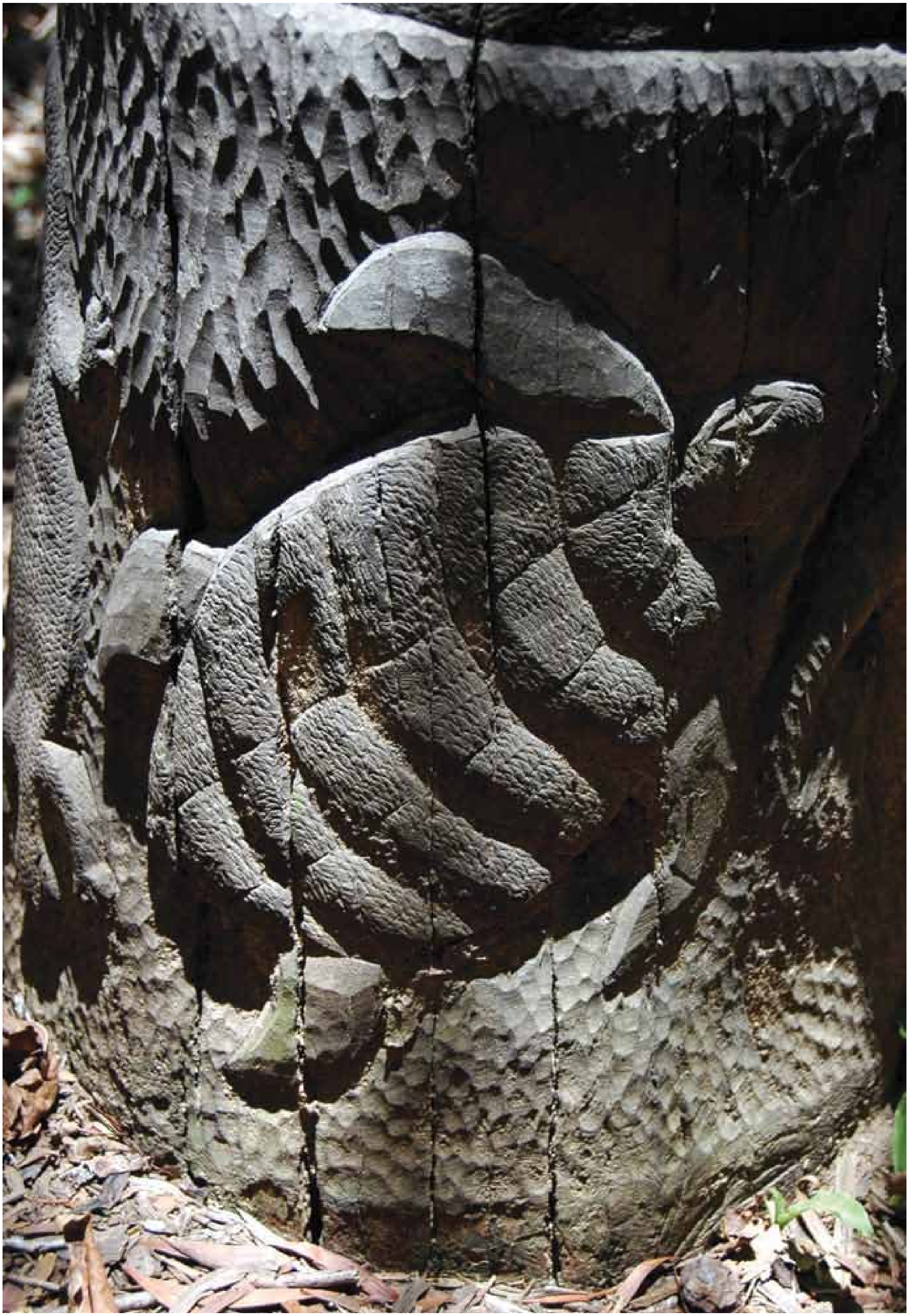


sekundo

Ecosystem diversity finds expression in the diversity of regional cultures and identities (traditional turtle sculpture in New Caledonia)

5. Macaronesia

Author: Jérôme Petit (IUCN)

Introduction

5.1

Macaronesia consists of a group of several islands scattered in the North-East Atlantic. This biogeographic region includes the Canary Islands (Spain), Madeira (Portugal), and the Azores (Portugal), which are outermost regions (OR) of the European Union, and Cape Verde. The group of islands' name comes from the greek *makaros* and *nesios*, and means the blessed or fortunate islands (Wirtz, 1994). The Macaronesian islands are of volcanic origin and are characterized by very steep landscapes. The Teide volcano on the Island of Tenerife in the Canaries culminates at an altitude of 3,718 metres. Macaronesia climate varies from cool humid on the Azores to sub-tropical climate on the Canary Islands . With a population of about 2 million people, the Canary Islands are the most populated European overseas entity.

Biodiversity

The Macaronesian islands share several geological, biological and climatic characteristics. These archipelagos are of volcanic origin and were therefore never attached to any continent. As a result, they display particularly high levels of animal and plant endemism. The biodiversity of this region consists of a blend of the biological families found in the North Atlantic, the Mediterranean and Africa. Given their high altitude, the Macaronesian islands present significant climatic variations. The trade winds that blow from the north-east are responsible for creating a cool humid climate in the areas exposed to them. In the summer, at an altitude of between 700 and 1,500 metres, these winds create veritable "seas of clouds" as they encounter the islands topographic barriers, with humidity as high as 85% which encourage the growth of lush vegetation on the windward slopes of the islands. Above 1,500 metres, these wind currents disappear to give way to an arid climate characterized by hot dry summers and harsh winters. The southern-facing slopes and the west of the islands are not exposed to these winds and their climate can be extremely dry. One of the distinguishing features of Macaronesia is the persistence of species that are extinct on the continents. The Laurel forest, which is unique to this region, is a veritable forest relic. It resembles erstwhile European forests prior to the last glacial period. The Macaronesian archipelagos have managed to retain a large part of this ancient vegetation thanks to the thermoregulatory capacity of the surrounding ocean. Macaronesia is also home to an exceptional marine biodiversity. It has a unique diversity of sea mammals, with 29 species of cetaceans observed in the Canary Islands. The waters around these three European archipelagos are home to 5 species of marine turtles.

Current threats

High population density (200 inhabitants/km² on average) and mountainous landscapes mean that the inhabitants are obliged to colonize all the available plains to the detriment of the wooded areas; the natural forests were severely eroded with the arrival of the first human settlers. Recently, tourist infrastructure has spilled over into the coastal areas. Added to these pressures are threats from invasive species and repeated fires which disrupt the equilibrium of the ecosystems.

Climate projections for the region

Climate change projections vary among archipelagos (Santos and Aguiar, 2006; Sperling et al., 2004). Nevertheless, according to IPCC models, the average annual temperature in Macaronesia is set to increase by 2.1°C [1.9 to 2.4] between now and 2099. A significant temperature increase has already been observed in the whole region. Rainfall predictions are less clear.

Climate change could have a major impact on the wind patterns in these archipelagos, and particularly on the trade winds. A drop in the strength of the trade winds has already been observed over the last 30 years. This has been attributed to a change in the circulation of atmospheric air caused by climate change (Sperling, 2004). A decrease in the trade winds causes the "sea of clouds" to drop to lower altitudes. A drop in temperature and an increase in the relative humidity have been observed during the dry season at altitudes well below those usually influenced by these winds (Sperling 2004). A decrease in the strength of the trade winds also leads to an increase in the prevailing eastern winds from Africa. This inversion of the wind regime is likely to be accompanied by an inversion of the bio-climatic zones of these islands (Donner-Wetter, personal communication).

Finally, IPCC predictions point to a rise in the sea level of 0.35 metres between now and the end of the century; this corresponds closely with the predicted global average rise in sea levels (IPCC, 2007).

Impacts of climate change

A change in the wind regime, and particularly a drop in the north-westerly trade winds, would lead to a drying up of the coasts on the exposed islands. The Laurel forest would in all likelihood be disrupted by a downward drift of the "sea of clouds" (see Box 5.5). The general desertification of the islands would pave the way for the invasion of alien species, especially African species that are adapted to dryer conditions, to the detriment of indigenous species. More than 30 species of Saharan birds were recently observed for the first time in the Canary Islands (see Box 5.2). Similarly, tropical fish species, which usually live further south, have also been spotted in the waters of the Azores Madeira and the Canary Islands (see Box 5.8). Swarms of pilgrim crickets (desert locusts) that affect West Africa could become more frequent in the Canary Islands. In 2004, a swarm of more than 10 million locusts descended on the coasts of Lanzarote (see Box 5.1). Finally, a rise in the water temperature is likely to lead to outbursts of harmful microalgae becoming more often, with negative consequences for public health. In 2004, a wave of algae was observed in the waters around Gran Canaria (see Box 5.3).

Table 6: Climate variations between now and the end of the century for Macaronesia (IPCC, 2007).

Average for 21 global simulation models (scenario A1B). Margin of uncertainty in brackets (25/75% quartiles).

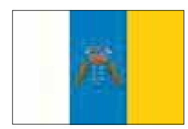
Climate indicator	Variation between 1980-1999 to 2080-2099
Air temperature	Increase of 2.1°C [+ 1.9 to +2.4]
Precipitation	Increase of 1% [-3% to +3%]
Wind regime	Decrease in the power of the north-westerly trade winds, increase in he prevailing eastern winds
Sea level	Average rise of 0.35 metres [+0.23 to +0.47]

JrGMontero

East winds from Africa bring Saharan sand to the Canary Islands

Matarpada

Canary Islands



5.2 Canary Islands (Spain) OR

Number of islands:	7 main islands
Population:	2 025 951 inhabitants (2008)
Area:	7 447 km²
Population density:	272 inhabitants / km²
GDP/inhabitant:	n/a
Unemployment rate:	n/a
Economic activities:	tourism

The Canaries archipelago is an autonomous region of Spain whose eastern-most point is only 100 kilometres to the west of Morocco. The region consists of seven main islands: Tenerife, Fuerteventura, Gran Canaria, Lanzarote, La Gomera, El Hierro and La Palma. With a population of about 2 millions inhabitants it is the most populated European overseas entity. The islands have very rugged landscapes as a result of recent – and in some places current – volcanic activity. The El Teide volcano on the island of Tenerife, which culminates at 3,718 metres, is the highest summit in Spain. The tertiary sector and tourism in particular, with more than 10 million visitors a year, account for 75% of the economy of the Canaries. Agriculture plays a minor role in the islands' economy. Only 10% of the islands' land area is cultivated (cereals, vines, bananas, tomatoes and tropical fruit).

5.2.1 Current state of biodiversity

Remarkable habitats and species

The Canaries archipelago is one of the biologically-richest temperate zones in the world. The rate of endemism is very high for plants (21 %), reptiles (100 %) and invertebrates (39 %) (Esquivel et al., 2005). The Canary Island's vegetation, which includes a total of 1,992 vascular plants, has been shaped by natural factors such as altitude, exposure to the elements, soil type, influence of the north-trade winds, but also by human intervention which has modified the original spatial distribution of the vegetation. In addition to their rich plant species, the Canary Islands are also home to five species and 31 sub-species of endemic birds (Esquivel, personal communication). Among them, the Bolle's laurel pigeon (*Columba bollii*), the White-tailed pigeon (*Columba junoniae*) and the Blue chaffinch (*Fringilla teydea*) are threatened. The La Gomera giant lizard (*Gallotia gomerana*) is another iconic endemic species of these islands.

The Canary Islands have five main major habitats: xerophytic shrub, thermophilous forest, laurel forest, pine forest, and high mountain shrub. Precipitation is low and exposure to the sun high in the zones between sea level and 400 metres of altitude; the vegetation in these zones is dominated by euphorbias, and principally the *Euphorbia canariensis* cactus, succulent plants that are perfectly adapted to the dry conditions in these zones. Between 300 and 700 metres, the forest cover is dominated by thermophilous forests that are adapted to the more gentle climatic conditions. Species which inhabit these areas include shrubs like the Drago tree (*Dracaena draco*), the Canarian palm tree (*Phoeonix canariensis*), the Olive tree (*Olea cerasiformis*) and the Juniper tree (J*uniperus turbinata*). Higher up, situated between 600 and 1,100 metres of altitude, the Laurel forest is a relic wood from the Tertiary Period (see Box 5.5). This vegetation, only found in Macaronesia, is a conservation priority. Some of the iconic species include: *Laurus novocanariensis, Persea indica, Erica arborea* or *Myrica faya*. It is found in the humid north-trade-wind influenced "sea of clouds" zone. Higher up are the pine forests, dominated by the endemic *Pinus canariensis*, a species that is well-adapted to the harsh climatic conditions prevailing in this zone. This vegetation is the most widespread on the territory. Lastly, the high mountain shrub is mainly constituted by endemic species. This habitat is mostly represented in the islands of Tenerife and La Palma, where species such as *Spartocytisus supranubius*, *Adenocarpus viscosus*, *Pterocephalus lasiospermus* or *Viola cheiranthifoli*a are present.

The marine biodiversity of the Canary Islands is just as exceptional. Deep water coral reefs composed mainly of *Lophelia pertusa* surround these islands at depths of 50 metres. The Canary Islands are a major hotspot for marine mammals: 29 of the 81 species of whales that exist in the world are found in the waters of the archipelago. There are also four species of marine turtles; however, the latter do not reproduce on the islands (Esquivel, personal communication). There are 145 protected areas in the Canary Islands, including four terrestrial national parks. The small island of El Hierro is a UNESCO biosphere reserve.

Current threats

Direct destruction of habitats, over-exploitation of resources and invasive species are the three principal past and present threats to the biological diversity of the Canary Islands. The vegetation of the dunes and coastal *Tamarix* forests have been destroyed or fragmented by urban and tourist development. The low-lying euphorbia shrubs have been damaged by pasture and urban development. Similarly, the sclerophyllus woods (thermophilous forest) have seen their surface areas considerably diminished, because of their proximity to human settlements. The pine forests, for their part, are very vulnerable to fires. Over-exploitation of the forests for wood has had a major impact on these ecosystems in the past. Just about all the thermophilous forests and a large section of the Laurel forest have been lost to massive deforestation. The pine forests, for their part, have been able to regenerate thanks to reforestation programmes.

The biodiversity of the Canaries has also been damaged by invasive species whose rate of introduction has increased since the abolition of border controls following the entry into force of the Schengen Accords about 10 years ago. Among these are the Barbary ground squirrel (*Atlantoxerus getulus*), which has decimated numerous plant species on the island of Fuerteventura, and the very aggressive Argentine ant (*Linepithema humile*), whose rapidly growing colonies are pushing out indigenous ants and other insects from their habitats.

Paola Farrera

Sea of clouds below the El Teide mount

5.2.2 New threats resulting from climate change

Most of the actors in the field who were consulted considered climate change to constitute a secondary threat to biodiversity. The main threat, according to them, remains ecosystem destruction as a result of urbanization and over-exploitation of resources. That said, the potential impacts of climate change on the plant formations of the Canary Islands have been well documented. There are fewer data relating to marine ecosystems.

Impacts on terrestrial biodiversity

A change in the wind patterns, and particularly in the direction of the north-trade winds, seems to be the most damaging climate variation to the region's biodiversity. The cool, humid north-trade winds, could see their current north-south direction inverted to become east-west. As a result of this, the humid coastal areas in the north of the islands could become dryer, while conversely, the currently semi-desert southern coasts could become more humid. These changes could lead to the migration of numerous species; those that are unable to migrate run the risk of declining. The endemic hydrophile species such as the Canary willow (*Salix canariensis*) or the Canary Island Date palm (*Phoenix canariensis*) will be particularly affected.

The five previously-described habitats of the Canary Islands could also be perturbed by a change in the wind direction, as well as by the resulting changes in temperature and precipitation (Del Arco, 2008). The euphorbia shrubs could spread out, while the thermophilous forests will tend to contract. The latter already have a very weak resilience because of their high fragmentation and slow rate of growth. The Laurel forests are almost certainly the most vulnerable to climate change. They will be directly affected by a change in the direction of the trade winds (see Box 5.5). The pine forests, for their part, could be more vulnerable to forest fires which are likely to be more frequent because of the rise in temperatures and the drop in precipitation. During summer 2007, a violent fire destroyed close to 35,000 hectares of forest, affecting practically the entire habitat of the Blue chaffinch (*Fringilla teydea*) on Gran Canaria Island. Finally, the high altitude ecosystems will also suffer the effects of

Box 5.1: 100 Million Pilgrim Crickets (Desert Locusts) in Lanzarote in 2004

The pilgrim cricket or desert locust (*Schistocerca gregaria*) is a red-coloured insect of the orthoptera order that can grow as large as 8 centimetres in length. These insects hatch in the warm regions of North Africa in the autumn. In the spring, they congregate and travel in swarms, carried by the winds, in search of more abundant food supplies. This species can remain harmless for several years; however, when the right climatic conditions prevail, these crickets can reproduce on a massive scale, congregate in swarms of several km², and destroy most of the crops in their path. The FAO estimates that a swarm of 50 million locusts can devour up to 100 tonnes of fresh vegetation a day (FAO, 2004). The optimum climate conditions which lead to these infestations include a combination of high temperatures accompanied by strong droughts, which increase the life expectancy of these insects, followed by heavy rains, which result in a surge in the vegetation and facilitate the reproductive capacity of the locusts. In 2004, these climatic conditions were all united in West Africa and swarms of particularly devastating locusts formed in this region. The south-easterly winds which were blowing at the time carried the locusts to the Canary coasts. In Lanzarote and Fuerteventura, an estimated 100 million insects landed on the coasts, which represented some 50 insects per m². The autonomous government reacted to this emergency, and huge volumes of pesticides were deployed to combat this invasion (Martin, 2004). Local environmental associations voiced their concerns about the collateral damage caused by these chemical products to the indigenous entomofauna. The locusts that made it to the Canary Islands were already adults and at the end of their lifecycle. The crop damage was therefore relatively limited. Approximately 1% of the crops were destroyed in Fuerteventura. But the damage in North Africa was particularly severe that year. The locusts devastated about 80% of the cereal crops in Mauritania (CSIC, 2004). Plagues of locusts like that of 2004 are very rare in the Canary Islands; the last major plague was in 1954. However, with a rise in temperatures and drought, such plagues could become more common place.

Pilgrim crickets in Lanzarote in 2004

Pilgrim cricket (*Schistocerca gregaria*) rising temperatures, because they will be unable to migrate to higher altitudes. The subalpine *Bencomia exstipulata or Rhamnus integrifolia* for example, are already on the verge of extinction; drought would almost certainly make them disappear definitively. At the coastal level, a rise in sea levels could affect the vegetation of the dunes and beaches and bring about major changes in the coastal landscape.

In addition, the introduction of invasive species and the extension of the spatial distribution of existing invasive species could also be among the major consequences of climate change. In particular, numerous species of African origin could settle in the Canaries, attracted by dryer climatic conditions. The African fountain grass (*Pennisetum setaceum*) for example, a grass which develops on high grounds, is already present in the Canaries, but is currently limited to the arid lands. It could see its area of spatial distribution extended. Warmer summers could also lead to massive plagues of African locusts (see Box 5.1). New bird species, originally from the Sahara region, have also been observed recently in the Canary Islands. (see Box 5.2).

Box 5.2: New birds from the Sahara in Fuerteventura

Some 30 species of birds of Saharan and sub-Sahel origin were recently observed in the Canary Islands by the Global Nature Foundation; they have never before been spotted in the region. Among the new arrivals identified were the Greater Hoopoe lark (*Alaemon alaudipes*), the White-crowned wheatear (*Oenanthe leucopyga*), the Long-legged buzzard (*Buteo rufinus*), the Desert wheatear (*Oenanthe deserti*), the Asian desert warbler (*Sylvia nana*) and the Egyptian nightjar (*Caprimulgus aegyptius*) (Martin & Lorenzo, 2001). The presence of some species is sporadic, while others, such as the Laughing dove (*Streptopelia senegalensis*) or the Ruddy shellduck (*Tadorna ferruginea*), have begun to nest on Fuerteventura in the last five or so years (Global Nature 2008). Desertification of this island might be responsible for these introductions, but stronger data are necessary to confirm this hypothesis.

There has been a general wave of birds from warm regions moving north as a result of climate change, either in an attempt to flee the arid conditions in their area of origin, or in search of warmer conditions in the Nordic regions. A recent report by the RSPB suggests that the spatial distribution of all European birds could shift some 550 kilometres to the north between now and the end of the century; three-quarters of species will be unable to migrate and as a result will go into decline (RSPB, 2007).

An ornithological inventory is currently being drawn up in the Canary Islands by the Global Nature Foundation to gain a better understanding of the dedicated bird life on these islands and to measure the magnitude of the invasion by exotic bird species.

Laughing Dove (*Streptopelia senegalensis*)

Ruddy Shelduck (*Tadorna ferruginea*)

Desert Weatear (*Oenanthe deserti*)

Impacts on marine biodiversity

Many species of tropical fish were observed for the first time in Macaronesia because of the rise in water temperatures (see Box 5.7). For instance, the Ocean triggerfish (*Canthidermis suflamen*), a warm water fish, was recently observed in the vicinity of the Canary Islands. Climate change could seriously modify the composition and abundance of fish stocks in the region.

In addition, the Canary Island corals, largely made up of very fragile cold-water species, could also be threatened by a rise in temperatures and acidification of the sea water (see Box 5.6).

Finally, changes in climatic conditions have resulted in exceptional flowering of marine algae around the coasts of the Canary Islands (see Box 5.3). This phenomenon could increase in the region with a rise in water temperatures, and affect all the marine ecosystems.

Box 5.3: Tides of Algae in the Canary Islands

For the first time, 2004 saw the formation of a tide of algae in the waters of Gran Canaria and Tenerife. Dark stains appeared in the water in different places around the coast, mainly in Mogan and Palmas de Gran Canaria. These algae were in fact cyanobacteria of the Trichodesmium genus, containing coloured pigments. They are normally invisible in water because of their low concentration. However, unusual climatic conditions in 2004 led to exceptional blooming episodes in the Canary Islands (O'Shanahan, 2006).
A study undertaken by the University of Las Palmas de Gran Canaria demonstrated that this algal tide was the result of a rare combination of several climatic features. On the one hand, high temperatures facilitated the development of cyanobacteria; that year, the water temperature reached record highs with spikes of 29.5°C, or 3 degrees higher than the maximum temperatures recorded in the previous 15 years (Ramos, 2005). At the same time, the retreat of the north-trade winds created a vacuum that was filled by an influx of masses of warm air from the Sahara. This air carried dust particles which were deposited on the coasts of the Canary Islands. These particles contain iron, which acts as a nutrient for the oceans. An accumulation of large quantities of these particles causes an over-fertilization of the ocean and facilitates the development of cyanobacteria, which affect the whole of the marine ecosystem. This phenomenon is well-known in the Caribbean, because of the spectacular red tides it causes. Red tides are becoming increasingly common with climate change. Dust particles from the Sahara cross the whole of the Atlantic and are deposited in the Caribbean. Along with higher water temperatures, they cause massive flowering of the cyanobacteria. The resulting concentration levels are sufficiently strong to cause discoloration of the water (Walsh 2006). These red tides frequently lead to public health problems caused by the ingestion of sea food, as well as to high rates of mortality among the fish and seabirds. In the Canary Islands, algae flowering episodes are not strong enough to create red tides, but they could increase in frequency with a rise in the temperature of the water.

Nieves Gonzales

Trichodesmium alga containing color pigments

Leopoldo O'Shanahan

Tides of algae on Las Palmas coasts, Gran Canaria in August 2004

Socio-economic implications

The socio-economic implications of climate change in the region are numerous. The number of heat waves is likely to increase and will directly affect the human populations of these islands. In 2003, an exceptional heat wave accompanied by temperatures as high as 46°C in Lanzarote, led to the deaths of 13 people. A rise in temperatures could also facilitate the spread of tropical diseases, especially insect-borne diseases which could multiply rapidly. An increase in dust-charged winds from the Sahara could increase the incidence of allergies and respiratory problems.

Responses to climate change

A decrease in fish stocks would have an impact on the fishing industry. Aquaculture, a fairly recent activity in the archipelago, could also be affected by a change in climate conditions.

Finally, and most importantly, increased warming in the archipelago could seriously affect the tourist industry, the main economic pillar of the archipelago. An increase in the number of heat waves, like the one which hit the region in 2003, could discourage visitors during the summer months. Desertification of the natural landscapes would also reduce the attractiveness of these islands

Box 5.4: El Hierro: The First Energy Self-Sufficient Overseas Island?

El Hierro, an island of 10,500 inhabitants, is a UNESCO biosphere reserve. It hopes to become one of the first entirely energy self-sufficient islands. To do so will require the complete restructuring of the island's energy production facilities. The island has also received a 54.3 million Euro grant, whose disbursement is staggered until 2009. The project will prevent annual emissions of 18,700 tonnes of carbon dioxide. Most of the energy will come from a 10 megawatt hydroelectric power station. A windmill park (10 megawatts) will be used to fuel a pumping system to stock water in one of two reservoirs, and will provide a supplementary source of energy. The excess wind power will be used to fuel two sea water desalination factories. Water and wind should produce up to 80% of the island's energy requirements. Thanks to photovoltaic and thermodynamic panels, the sun should provide the rest. The island's current power station, which uses fuel and provides most of the island's electricity, will cease to operate at the end of its life. A programme to raise awareness of the importance of energy efficiency among the local population is also an integral part of this project.

The example of El Hierro demonstrates that energy self-sufficiency on the islands is possible with currently existing technologies. A combination of different energy sources will be necessary to make the system viable in the long-term; the exploitation of a single resource would render energy production uncertain and make it dependent upon meteorological conditions. Several other islands of continental Europe have already achieved energy self-sufficiency, including the Island of Samso in Denmark, and the Island of Vlieland in the Netherlands.

Wind turbine in El Hierro

IUCN/Jean-Philippe Palasi

Madeira

5.3 Madeira (Portugal) OR

Number of islands:	3 main islands and several islets
Population:	244 098 inhabitants
Area:	828 km²
Population density:	295 inhabitants / km²
GDP/inhabitant:	n/a
Unemployment rate:	n/a
Economic activities:	Agriculture and tourism

Madeira Archipelago is an autonomous region of Portugal situated in the Atlantic Ocean to the west of Morocco. It consists of 2 inhabited islands, the Island of Madeira (742 km²) and the island of Porto Santo (43 km²), three small islands known as Desertas (Ilhéu Chão, Deserta Grande and Bugio) and the small archipelago of Selvagens, with its two small islands (Selvagem Grande and Selvagem Pequena) and one islet (Ilhéu de Fora) and several other small islands. The capital of the archipelago, Funchal, is about 660 kilometres from the African coast and 980 kilometres from Lisbon. The island of Madeira, which represents 90% of the land of the archipelago, is of volcanic origin with steep slopes. With its sub-tropical climate and unique landscapes, it is a much appreciated tourist destination. At the time of its discovery by the Portuguese, the archipelago was uninhabited: the current population is descended from the colonizers, and mainly Portuguese. The population density, of about 300 inhabitants per km², is approximately three times higher than the Portuguese average. The region's economy is based essentially on agriculture and tourism. With 850,000 visitors a year (2005 estimate), tourism accounts for 20% of GDP. The bananas, flowers and wine produced on Madeira are destined for the local and metropolitan markets. There is little industry, but favourable fiscal conditions are attracting many international finance companies.

5.3.1 Current state of biodiversity

Remarkable habitats and species

Madeira is home to tremendous biodiversity, encompassing an estimated number of 7 571 terrestrial species for the whole archipelago. The total number of endemic species and subspecies is about 1419 (1 286 species and 182 subspecies), which represents 19% of the overall species diversity (Borges et al., 2008).The animal Phyla are the most diverse in endemic taxa, namely Mollusca (210 species) and Arthropoda (979 species), comprising about 84% of Madeiran endemics. Within vascular plants there are 154 endemic species and subspecies while the remaining higher taxonomic groups are less diverse in terms of endemic forms: 36 species of Fungi (5%), 12 Lichens (2%), 11 Bryophytes (2%) and 15 vertebrates (24%) (Borges et al., 2008),

There are 6 protected areas in the Madeira Archipelago: the Madeira Natural Park, Desertas Islands, Selvagens Islands, Ponta de São Lourenço, Rocha do Navio and one Marine Protected Area (Garajau). The Madeira Natural Park, which includes the entire Laurel forest, is a European Council Biogenetic Reserve since 1992, as well as a UNESCO World Natural Heritage site since 1999. It spans over 2/3 of Madeira

Island. Additionally, 11 sites in the whole archipelago are designated under the Natura 2000 network and 11 other sites are designated IBA's (Important Bird Areas).

The most celebrated environment of the archipelago is its Laurel forest which still extends over 15,000 hectares, or 20% of the archipelago. These forests, of tremendous biodiversity richness, are the largest and best-preserved Laurel forests in the entire Macaronesia. They are home to unique plant and animal species, including the famous Trocaz pigeon (*Columba trocaz*) and the Madeiran Firecrest (*Regulus madeirensis*), which has recently been elevated to the status of endemic species. The most threatened bird of Europe, the Madeiran or Zino's petrel (*Pterodroma madeira*) inhabits the highest cliffs at the Central Mountainous Massif.

In the waters around Madeira there are numerous species of marine mammals, including 28 species of cetaceans and the Critically Endangered (CR) monk seal (*Monachus monachus*) (Cabral et al., 2005) (IUCN Red List 2008). Also, 5 species of marine turtles are believed to use these waters during their pelagic life stage. Additionnaly, deep water coral reefs grow at depths of 50 metres around the islands.

Current threats

The most important threat hanging over the ecosystems of Madeira is direct habitat destruction. As soon as the first settlers arrived from Portugal, at the start of the 15th century, the island was deforested to make way for cereal fields and, later, sugar cane. The tourism industry is also occupying an important part of land, especially the coastal habitats.

Box 5.5: Laurel Forests Affected by a Change in the North Trade Winds

The Laurel forest is a forest system rich in endemic species and unique to Macaronesia. It is made up of trees that can grow to a height of 40 metres, such as the Canary laurel, *Laurus novocanariensis*, and is found in the humid mountainous areas of the islands. These "fossil" forests are relics of the Tertiary Period, which once covered most of the Mediterranean basin in the days when the region's climate was more humid, before successive glaciations. When the islands were discovered, Laurel forests covered almost the entire island; today they are found mainly on the north-facing slopes of the higher islands, in the deep and distant valleys of the interior, between 300 and 1,300 metres of altitude. The Laurel forest is composed of hygrophyte species of bush '*Erica spp.*), which develop in areas of high humidity because of the presence at this altitude of a veritable "sea of clouds", the area under the influence of the north trade winds. This forest, made up almost entirely of endemic species, is a conservation priority zone.

Under the influence of climate change it is likely that the Azores anticyclone will move east during the summer months. This will probably serve to diminish the frequency and intensity of the north-east trade winds. These weaker trade winds may have different effects on the ecosystems of the different islands of Macaronesia. In the case of Madeira Island, it may allow for warmer temperatures to reach higher altitudes, pushing the "sea of clouds" further up. Laurel forest will likely migrate upwards, displacing high altitude vegetation such as *Erica spp.*, and the mountain top vegetation would disappear (Santos and Aguiar, 2006). In contrast, the weaker trade winds will probably lead to a downward movement of the roof of the "sea of clouds" towards lower altitudes in islands such as Tenerife (Sperling et al., 2004). This will be accompanied by an increase in the number of heat waves in this zone. In any case, the direct consequence of these climatic changes will be a decline in the bio-climatic areas occupied by the Laurel forest, and as a result, an important reduction in this forest formation (Sperling, 2004). In the case of Tenerife, the migration of these forest formations towards lower ground seems improbable given that these areas are already highly urbanized. Furthermore, the pine and eucalyptus species, which are also likely to migrate to lower altitudes for similar reasons, will probably encroach on the areas occupied by the Laurel forest. These more aggressive species, with greater capacity to colonize, will be able to migrate more easily. The disappearance of the Laurel forest would be an important loss for the biodiversity of Macaronesia. Moreover, it would disrupt the hydric balance of the islands and water supplies for human consumption. Since horizontal or 'hidden' precipitation (i.e., the deposition of water droplets onto vegetation and soil surfaces through direct contact with clouds) represents substantial water input, it is of significant ecological importance to the ecosystems' balance, and provides ecosystemic services to local human populations.

Pano philou

Laurel forest are "fossil" forests endemic to Macaronesia

Browser

The Madeira Chaffinch (*Fringilla coelebs madeirensis*) is an endemic sub-species from Madeira

5.3.2 New threats resulting from climate change

Impacts on terrestrial biodiversity

The Madeira Laurel forests are the ecosystems of the archipelago most vulnerable to climate change, and particularly to a change in the intensity of the north-trade winds (see Box 5.5). Some of the island's plant species, which until now posed no threat, are able to take advantage of the changes in the climate which provide optimal conditions for their development. They are beginning to spread rapidly and their expansion is gaining ground on the indigenous forest. A change in the migratory habits of some of the archipelago's birds has also been observed recently. For example, a small number of Pallid swifts (*Apus pallidus*) now spend the entire year in Madeira and no longer migrate towards Africa in the autumn. Others leave for their winter destinations later or return earlier (Fagundes, personal communication).

Impacts on marine biodiversity

In recent years, the occurrence and/or increase in frequency of several warm-water species around Madeira may also be due to progressive warming of the water due to climate change (Wirtz et al., 2008). New records include the crab *Platypodiella picta* (Araújo and Freitas, 2003) and the fishes *Aluterus scriptus, Aluterus monoceros* (Freitas and Biscoito, 2002), *Abudefduf saxatilis* (Freitas and Araújo, 2006), *Gnatholepis thompsoni* (Araújo and Freitas, 2002), *Canthidermis sufflamen and Caranx crysos* (Wirtz et al., 2008), among others. Continued warming may lead to the appearance and establishment of additional tropical fish species at Madeira (Wirtz et al., 2008). In addition, the deep water corals of the archipelago are threatened by the acidification of the oceans (see Box 5.6).

Box 5.6: Deep Water Corals Threatened by Acidification of the Oceans

Madeira, the Azores and the Canary Islands are home to a large number of deep water coral reefs, consisting mainly of Lophelia pertusa, which develop at depths of 50 metres and are sometimes found as deep as 1,000 metres. These corals are part of a large belt of cold water reefs which stretch from Norway to West Africa (Lophelia.org). These ecosystems are seriously threatened by deep sea trawling, which destroys corals that have developed over several thousands of years. Since 2004, a European Commission amendment prohibits deep sea trawling less than 200 metres from the coasts of Madeira, the Azores and the Canary Islands. This destructive fishing practice is sadly not the only threat to the deep water corals. These organisms are also sensitive to the acidification of the oceans caused by an increase in the level of CO_2 in the atmosphere. A drop in PH levels reduces the rate of calcification of the corals and puts a brake on their growth and regeneration. Cold water corals are particularly threatened, because the depth at which they begin to dissolve (or the aragonite saturation point) could rise by several hundred metres (Doney, 2006). These are not the only organisms at risk; a reduction in PH levels could affect all marine organisms with calcium skeletons, including most tropical corals, but also urchins, some molluscs and several species of calcium-enveloped zooplankton (Orr, 2005). The consequences for the marine ecosystems as a whole would be considerable.

Deep waters corals like *Lophelia pertusa* develop at depths of 50 meters

agymono

Box 5.7: *Aedes Aegypti* Recently Reported in Madeira

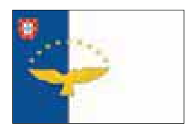
In 2004, the mosquito *Aedes aegypti* was reported in Madeira Island for the first time, This mosquito, locally known as 'St. Luzia mosquito' (the place where it was first detected), is the vector species of dengue fever and yellow fever. Resources were allocated to eradicate the species as well as to mitigate the spreading of its population. However, despite all the efforts, the mosquito has found favorable climate conditions to establish and proliferate and has become a major problem for the affected human population. It causes acute skin reactions and has been responsible for a few hundred people needing medical attention and the intervention of local public health authorities (Claudia Delgado, personal communication). A toll-free line was created to assist people with questions given the magnitude of the problem. The mosquito's population is not yet infected with viruses, but since Madeira is a tourist destination and has high immigration rates from South American countries as well as from South Africa, the chances that diseases such as dengue or yellow fever might be introduced to the region are significant. The arrival of the vector species of these tropical diseases together with the increasingly favorable climate conditions might require adaptation of public health policies (Santos and Aguiar, 2006).

Aedes aegypti

Muhammad Mahdi Karim

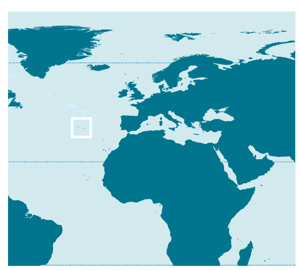
Vida de vidro.

Azores



5.4 Azores (Portugal) OR

Number of islands:	9 islands
Population:	241 700 inhabitants (2004)
Area:	2 333 km²
Population density:	103,6 inhabitants / km²
GDP/inhabitant:	12 487 Euros
Unemployment rate:	4.3% (2007)
Economic activities:	Agriculture and Fisheries



The Azores are an autonomous overseas region of Portugal and an outermost region of the European Union, situated in the centre of the Atlantic Ocean about 1,500 kilometres from Lisbon and Morocco and 3,900 kilometres from the east coast of North America. The Azores archipelago consists of nine islands with a total area of 2,333 km² of emerged land. It has a very humid oceanic climate with fairly minor annual variations. Mount Pico, on the island of the same name, reaches a high point of 2,352 metres of altitude and is the highest mountain in Portugal. The economy is primarily based on agriculture, with an annual production of 500 million litres of milk, or 25% of Portuguese milk production. Fishing brings in revenues of about 26 million Euros for the region each year, with 10 thousand tonnes of fish extracted from an exclusive economic zone of about a million km². The tourist industry is far less well-developed than those of Madeira or the Canary Islands, but tourist infrastructure has grown markedly over the last 10 years.

5.4.1 Current state of biodiversity

Remarkable habitats and species

Situated in an isolated region of the North Atlantic, the Azores behaves like a laboratory for natural evolution. Most of the species of the region are living fossils that resemble the pre-glacial flora of the European continent, such as the Laurel forest, which is typical of Macaronesia. The archipelago is home to an important diversity of endemic species that are found nowhere else. Among them the Azores bullfinch (*Pyrrhula azorica*), an endangered species with a population of about 250, included in the IUCN Red List, is restricted to the cloud forest on the east of the Island of Sao Miguel (McGinley, 2007).

Current threats

Since the arrival in the Azores of the first settlers, the indigenous flora and fauna have been under severe pressure from deforestation, agriculture and the introduction of invasive species. Only 2% of the original Laurel forest cover has been spared from deforestation. Exotic species of tree like the Japanese cedar (*Cryptomeria japonica*) or the Sweet pittosporum (*Pittosporum undulatum*) thwart the survival of the indigenous flora and fauna. The islands were once important nesting areas for seabirds, but the introduction of rats caused a decline in these populations which are now confined to the steep cliffs or small islets.

The important and recent agricultural development of the Azores has resulted in the conversion of approximately 50% of the natural spaces, which have been used as pasture to raise dairy cattle over the last 10 years. This development was in part a result of Portugal's entry into the European Union and the subsequent subsidies for which it is eligible (Mc Ginley, 2007).

Vida de vidro

he recent development of the dairy industry in the Azores had a big impact on biodiversity

The archipelago has no national park, and the protected areas which do exist lack legal protection (McGinley, 2007).

5.4.2 New threats resulting from climate change

Box 5.8: Migration of Tropical Fish to the Azores

Several species of tropical fish have recently been observed in the waters around the Azores. The Spined pygmy shark (Squaliolus laticaudus) was first spotted in 1998 (Silva, 1998) and the Lesser amberjack (Seriola fasciata) in 2006 (Silva, 1998; Machado, 2006). These recent sightings could be explained by a change in the spatial distribution of these species brought about by a warming of the waters. Similarly, the establishment and development of the green algae Caulerpa webbiana, an invasive species recently detected in the Azores, could be facilitated by rising water temperatures (Cardigos et al., 2006).

Numerous migrations of fishes have been observed in the waters of Europe. In the North Sea, a recent study analysed changes in the spatial distribution of several species of fish between 1977 and 2001. Of 36 species studied, 15 species like the Dover sole (Solea solea) and the Atlantic cod (Gadus morhua) have migrated further north in response to a warming of the waters by an average of 1.5°C (Perry, 2005). Some species have migrated up to 1,000 kilometres further north in less than 20 years (Quéro, 1998). By substituting themselves for native species, colonizing species can create huge imbalances in the ecosystems.

A. Hulbert

Seriola dumerili

treasuresofthesea

Caulerpa webbiana

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5.5

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6. Amazon Region

Author: Jérôme Petit

Introduction to the Amazon Basin

6.1

The Amazon is a tropical forest region which extends over close to 8 million km², or an area 14 times the size of France (FAO, 2001). It spans nine countries and territories: Brazil, Bolivia, Peru, Ecuador, Colombia, Venezuela, Suriname, Guyana and French Guiana. The Amazon River is the life blood of this forest; it supplies two-thirds of the fresh water on the planet.

Jami Dwyer

Burnt primary forest for agricultural land conversion in Brazil

The Amazon Basin is estimated to contain 50% of global biodiversity and 70% of plant species on the planet (Carazo, 1997). Recent inventories suggest that there are at least 40,000 plant species, 427 species of mammals, 1,294 species of birds, 378 species of reptiles, 427 species of amphibians, 3,000 species of fish and probably more than one million species of insect in the Amazonian tropical forest (WWF, 2007). These estimates are probably conservative, since a large number of ecosystems are as yet completely unexplored. It is believed that at least 50% of the region's species have not as yet been described by science (Carazo, 1997).

Since the last century, the Amazon forest has suffered serious deforestation, which has accelerated considerably over the last few decades. Large areas of forest are still being cleared for their wood, or to make way for agriculture and animal husbandry. According to FAO estimates, the Amazon was deforested at a rate of 4.3 million hectares per year between 2000 and 2005 (FAO, 2005). CO_2 emissions resulting from the destruction of the forest accounted for some 22% of global emissions (IPCC, 2007) and were responsible for a large proportion of the increase in the greenhouse effect. Annual CO_2 emissions resulting from deforestation in the Amazon basin are estimated at between 150 and 200 million tonnes (Houghton et al., 2000).

Box 6.1: The Lungs of the Planet in Danger

Growing forests absorb carbon dioxide from the atmosphere and convert it to wood through a process of photosynthesis. However, trees also emit CO_2 through evapo-transpiration and the decomposition of dead vegetation. Mature forests are thus usually considered carbon neutral because the absorption by photosynthesis is balanced by transpiration. However, it has been demonstrated that mature forests like the Amazon rainforest can react to human-induced increases in atmospheric CO_2 by an increase in their own productivity, and thus by absorbing more CO_2 than they emit. This phenomenon is known as the "CO_2 fertilisation effect" (Norby et al., 1999). Estimates indicate that the Amazon basin "carbon sink" sequestered some 3.1 million tonnes of carbon between 1980 and 1994 (Melillo, 1998). Forests could therefore limit climate change by reducing the quantity of CO_2 in the atmosphere, thereby acting like a green lung for the planet.

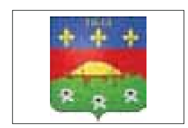
However, by that same token, a possible increase in temperatures in the Amazon basin could also lead to an increase in transpiration thereby increasing the amount of carbon dioxide released into the atmosphere. An increase in the rate of transpiration could also lead to a drop in precipitation in the region and reduce the productivity of the forest and the rate of carbon sequestration (Fearnside, 2000). Thus, variations in temperature and precipitation could transform the Amazon basin carbon sink into a fresh source of carbon, which would add to the already significant emissions caused by the continual deforestation of this forest massif.

NASA

Forest absorb Carbone dioxide from the atmosphere through photosynthesis

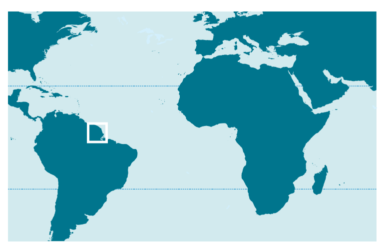
Nicholas Laughlin

French Guiana



6.2 French Guiana (France) RUP

Population:	230 000 inhabitants (2005)
Area:	86 504 km²
Population density:	2,7 inhabitants/km²
GDP/inhabitant:	11 935 euros (2006)
Unemployment rate:	24,5 % (2004)
Economic activities:	Aerospace industry, State subsidies



French Guiana is a French overseas territory to the north of Brazil. It is the only European territory in South America and the only outermost region (OR) of the European Union on the continent. Its area of 86,504 km² is the equivalent of one-sixth of the area of France, or the area of Portugal. French Guiana has an equatorial climate, with average temperatures of 27°C and 70 to 90% humidity. The 230,000-strong population of French Guiana is highly multi-cultural and includes: Creoles, Amerindians, Maroons, Metropolitans, Hmongs, Chinese, Lebanese, etc. Population density is low with 2 inhabitants per km², while the demographic growth rate of 3.8% is very high. French Guiana's economy is largely dependent on subsidies from Metropolitan France and the aerospace industry. At 24.5%, the rate of unemployment is one of the highest in overseas Europe.

6.2.1 Current state of biodiversity

Remarkable habitats and species

The department of French Guiana is home to an unparalleled biodiversity. This little corner of the Amazon is home to some unique ecosystems which are among the richest and most fragile in the world: primary tropical forests, mangroves, savannahs, and numerous types of wetland area.

With 83.1% of its territory covered by equatorial rainforest, French Guiana is home to the largest forest in France. The under-growth in this region is so dense that it only receives 1% of the sun's light and 25% of rainwater; the rest is captured by the forest canopy. Ironically, French Guiana's tropical forest has grown up on one of the poorest soils in the world in terms of nutrients and organic matter. However, this region was always preserved from the effects of glaciation, which explains its tremendous biological diversity.

No less than 5,750 plant species, 718 species of birds, 183 species of mammals, 480 species of freshwater fish and 108 species of amphibians have been inventoried in French Guiana (Gargominy, 2003). The inventory of invertebrates is in its infancy, but it is likely that the diversity of this family is 10 times greater than that of mainland France.

Some 92% of French Guiana's coastline and all the banks of its estuaries are covered in mangroves. Subject to the rise and fall of the tides, they provide shelter to a very distinctive fauna and flora. They act as nurseries for the marine fauna that take advantage of the abundant volume of organic matter shed by the mangrove trees. The environments also provide nesting and feeding sites for a large number of birds.

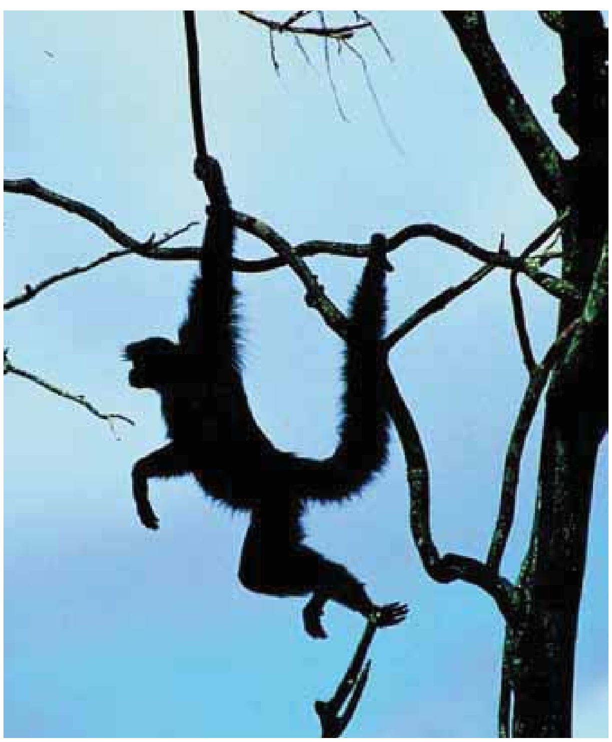
Five species of marine turtle are found in the waters and on the beaches of French Guiana. Awala-Yalimapo beach is the most important breeding ground in the world for the Leatherback turtle (Dermochelys coriacea), the largest of the marine turtle species (Gargominy, 2003).

French Guiana National Park, created in February 2007, is the largest protected area in the European Union. It has a surface area of 3.39 million hectares and includes within its perimeter the banks of the largest rivers in French Guiana, the Maroni and the Oyapock, which form the borders of Suriname and Brazil respectively (French Guiana Park site).

Current threats

The main threats to the French Guiana ecosystems include fragmentation by roads, illegal gold panning and poaching.

Road development remains limited in the department when compared with other forests of South America. Forest exploitation is therefore restricted by lack of access. However, recent developments, like the RN2, which crosses the forest massif through the north-west and joins up with Brazil, have further facilitated the fragmentation of the ecosystems and the introduction of invasive species. The poaching of protected species like the Collared peccary (*Pecari tajacu*), species of Red Spider monkey (*Ateles* sp.) or the Jaguar (*Panthera onca*), has also been facilitated by the opening up of the roads.



Stan Butler

Artisanal and industrial gold panning also lead to the local destruction of forest habitats, as well as to significant pollution of the rivers and the water table by mercury (used for extracting gold) and waste mud. Gold panning, especially illegal gold panning, affects all the large rivers and French Guiana, even those within the National Park

6.2.2 New threats resulting from climate change

Climate projections for the region

According to IPCC projections, between now and the end of the century, average annual temperatures in French Guiana could increase by 3.3°C [2.6 to 3.7], with the most marked increase of 3.5°C [+2.7 to +3.9] taking place in June-July-August

Levels of precipitation are also likely to undergo a change, with an increase in rainfall of 4% [+0 to +1] during the months of December-January-February and a reduction of 3% [-10 to +2] in June-July-August, during the dryer months (IPCC, 2007) (see Table 7).

Several recent studies have also highlighted the link between deforestation and precipitation in the Amazon rainforest. High resolution satellite images point to significantly higher levels of rainfall above deforested zones and a change in the patterns of precipitation for the region as a whole (Chagnon, 2004).

Table 8: Variations in climate between now and the end of the century for the Amazon region (IPCC, 2007).

Average for 21 global simulation models (scenario A1B). Likely range of uncertainty in square brackets (25/75% quartiles).

Climate indicator:	Variation between 1980-1999 to 2080-2099
Air temperature:	Increase of 3.3°C [2.6 to 3.7]
Precipitation:	Annual stagnation, but with an increase of 4% [0 to 11] in winter and a decrease of 3% [-10 to +2] in summer
Sea level:	Rise of 0.35 metres [+0.23 to +0.47]

Impacts on biodiversity

Higher temperatures and a drop in precipitation during the dry season will in all likelihood lead to longer and more severe droughts in the Amazon region, giving rise to a drying out of the tropical forests (see Box 6.2). Such conditions will considerably increase the risk of forest fires (Nepstad et al., 2004). Some studies already show that the number of fires has increased significantly in the region on account of a change in climate conditions (Cochrane, 2003). Furthermore, ecosystemic modelling using climate projections has pointed to a potential decline in the productivity of the tropical forest, that is to say, in the amount of carbon sequestered, as a result of a reduction in precipitation. This decline could have major repercussions on the global carbon cycle (Cox et al., 2004). In fact, climate change could modify the current status of the Amazon forest from a carbon sink to a source of carbon, which would eventually result in an increase in the global level of CO_2 in the atmosphere.

In addition, an increase in sea levels could lead to a reduction in the area of mangroves of about 1% per year (WWF, 2007).

Box 6.2: The Amazon Forest: A Future Savannah?

According to Brazilian researchers, between now and 2100 the Amazon could become a savannah. During the course of 2005, the surface temperatures of the tropical North Atlantic were particularly high; this led to the formation of a depression above this zone. This depression modified the wind regime above the entire Amazon region and significantly reduced the amount of rainfall, leading to the most serious drought ever observed in the region. Rivers dried up, thousands of km² of fires burned, releasing 100 million tonnes of CO_2 into the atmosphere (Marengo, 2008). A sustained increase in Atlantic Ocean temperatures, such as those observed in 2005, could profoundly affect the Amazon forest. A study undertaken in Brazil analysed the effects of climate change on the Amazon forest using IPCC predictions. The results are alarming. Under the worst case scenario put forward by the IPCC, an increase in temperatures of between 5 and 8 degrees accompanied by a 15% drop in precipitation could transform the Amazon landscape into a savannah (Marengo, 2006). The consequences would be considerable, not just for the biodiversity of this region, but also for the global carbon cycle.


vdossche

In 2005, Amazon experienced the bigger drought never observed

Box 6.3: Biodiversity of the Threatened Tropical Forest

The Amazon forest is home to highly specialized plant and animal species, at times with a very limited geographical distribution. A recent scientific study analysed the spatial distribution of 69 species of angiosperm plants (seed plants) in relation to IPCC climate predictions between now and the end of the century. A map of the potential distribution of these species was drawn up taking into account the temperature and rainfall conditions necessary for their germination, their growth and their survival. The results showed that 43% of the species studied would become non-viable between now and 2095 on account of a radical change in their spatial distribution caused by temperature and rainfall variations. Under the predicted climate change variations, these species would have no more areas to which to migrate, or their new spatial distribution would be too removed from their current habitats to enable migration. Plants with a limited spatial distribution and short generations are likely to be the most impacted (Miles, 2004). This study clearly illustrates that the complex ecosystems of the tropical forest and the highly adapted species will not always be able to acclimatize themselves to changes, even very minor ones, in climate conditions (Woodward, 2004).


IUCN/Jean-Philippe Palasi

Tresor Natural Reserve

Socio- economic implications

A change in climate conditions in the region will no doubt affect agriculture. A drop in precipitation during the critical months could reduce harvests and facilitate the spread of pests. Under these conditions greater surface areas will be needed to feed the population, which will speed up the process of deforestation (WWF 2007).

Furthermore, it has already been shown that extreme climatic conditions, which sometimes lead to floods, can engender important epidemics of insect-borne diseases like malaria and dengue fever, as well as other infectious diseases like cholera or meningitis (ONERC, 2006). The incidence of dengue fever has increased in French Guiana since the 1960s (Gagnon, 2001).

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6.3

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7. Polar and Sub-Polar Regions

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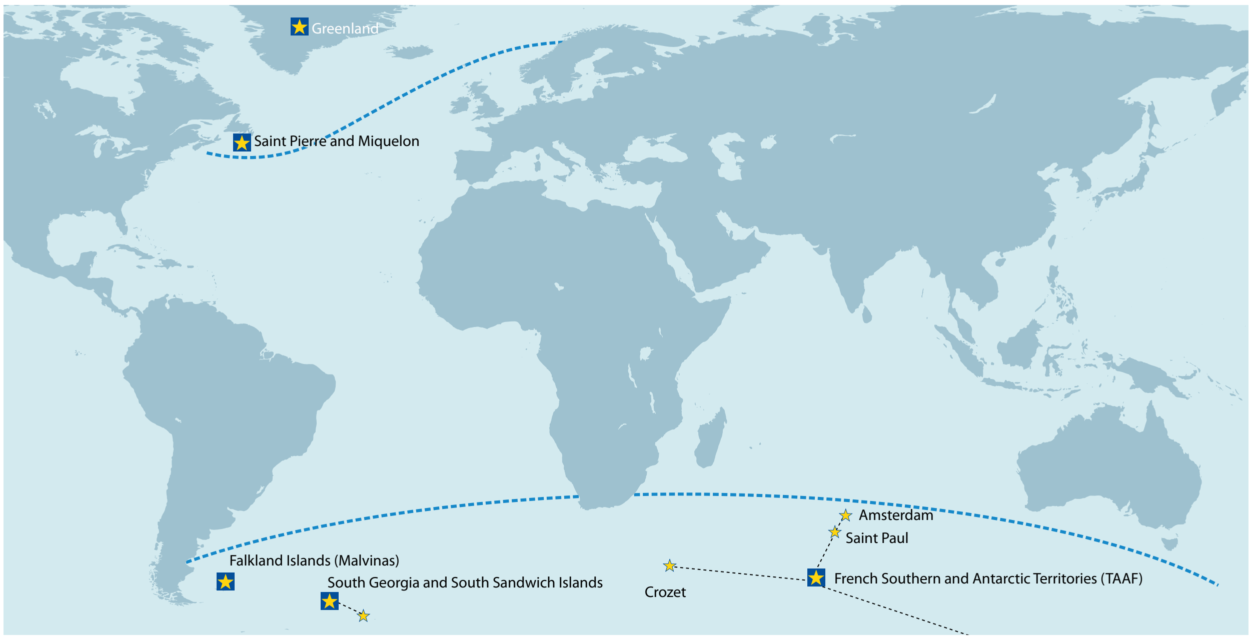
Introduction

7.1



The polar environments are lands of extremes and lands of tremendous riches. These regions are characterized by a wealth of resources, tremendous marine biodiversity richness and extreme prevailing climate conditions. The temperatures are particularly low, in some areas the winds blow semi-permanently reaching speeds of 200 km/h, and precipitation is either very abundant or very limited depending on the territory. In the north, the Arctic is characterized by an ocean surrounded by continental environments, while in the south, the Antarctic is a frozen continent surrounded by a cold ocean and a belt of sub-Antarctic islands. These natural climatic extremes have acted as barriers to human colonization with the result that human incursions into these environments have remained limited and few permanent populations currently inhabit these territories. The Polar Regions include six European overseas entities (OCT): Greenland (Denmark) and Saint Pierre and Miquelon (France) in the north; the British territories of the Falkland Islands (Malvinas), South Georgia and South Sandwich, and the British Antarctic Territories in the south; and the French Southern and Antarctic Territories (French acronym TAAF) also in the south. Territories located at latitudes greater than 60° South (Terre Adélie in the TAAF territory and the British Antarctic Territory) are considered overseas entities (OCT) by the European Union; however, under the Antarctic Treaty of 1959, these territorial claims are currently held in abeyance (i.e., put aside).

Biodiversity

The defining characteristics of the terrestrial ecosystems of the polar environment are their difficult living conditions due primarily to the harshness of the climate. Low temperatures, strong winds, poor soils, and prolonged periods of light and darkness have strongly conditioned the species of these environments. As a result, species have become highly specialized and adapted to these surroundings. In general, Arctic biodiversity is characterized by small numbers of endemic species. However, this is not the case in the Antarctic, where diverse and high biomass marine communities include very high proportions of endemic species (Clarke & Johnston, 2003), and even simple terrestrial ecosystems with very low diversity host a considerable number of endemic species (Convey & Stevens, 2007; Pugh & Convey, in press). The terrestrial food chains in the Arctic are relatively simple consisting of a few plant species, one herbivore and one predator (mammal or bird) per region. These are simplified yet further in the Antarctic, where indigenous terrestrial and freshwater vertebrates are absent, with the exception of a single passerine on South Georgia, and three species of duck in South Georgia and Kerguelen (Convey, 2007a, b). The vegetation is often dominated by low-to-the-ground plants including mosses, lichens, a few vascular plants, and tree coverage consisting of dwarf or creeping species. In contrast, in both polar regions, marine biodiversity is relatively rich, due to the presence of significant numbers of plankton in the cold waters and in the mixing zones where cold sea water mingles with warmer waters. Important populations of crustaceans, pelagic and benthic species which provide basic food for the many marine birds, toothed whales and baleen whales that inhabit the polar waters.

Current threats

Direct pressure exerted by human settlements on the ecosystems of these regions is for the most part scant when compared to the strong impacts of human activities in densely populated territories. However, these territories are subject to some very real threats. In Antarctica it should, however, be noted that the very restricted ice-free ground surface area means that impacts of even small and transient human research and tourist activities are magnified as humans, animal populations (birds and seals) and native terrestrial ecosystems are in effect competing for the same very limited available spatial resources. To start with, invasive alien species exert substantial pressure on the terrestrial biodiversity of the Polar Regions (Frenot et al., 2005, 2007; Convey, 2007c). The marine ecosystems are also subject to considerable stress as a result of fishing activities. The unlimited exploitation of seal and whale populations has driven some of these species to the brink of extinction. Today, these activities are subject to strict controls and the populations have since recovered to a lesser or greater extent. Pollution caused by Persistent


Jean Philippe Palasi

Southern Elephant Seal (*Mirounga leonina*) on Crozet island (TAAF)

Organic Pollutants (POP) also poses a serious threat in the north; this has been highlighted by the increasingly desperate plight of polar bears. Occasional disruption of marine birds during their nesting is commonplace in the north and in the south. Marine birds are also negatively impacted by fishing equipment including fishing nets, fishing hooks and other fishing equipment used for non-specific or non-discriminatory catches. Terrestrial and marine ecosystems are, thus, already under considerable anthropogenic pressure which is likely to be exacerbated by climate change.

Climate projections for the region

Air temperatures in the Arctic have already increased by twice the global average. Since the 1960-1970s, the Arctic has warmed by 1 to 2°C, depending on the region, and average temperatures could rise by as much as 4.9°C between now and the end of the 21st century (IPCC, 2007) (see Table 8). The increase in temperatures will likely be more marked in winter (+6.9°C) than in summer (+2.1°C). In Antarctica, temperature trends vary greatly from one


rtomazela

Rockhopper Penguins (*Eudyptes chrysocome chrysocome*) in Falkland Islands (Malvinas)

sub-region to another. While the Antarctic Peninsula has warmed significantly over the last 50 years, the region surrounding the geographical South Pole has cooled slightly (IPCC, 2007). Until now, precipitation patterns have not changed significantly in the Arctic, while evidence of decreases has been observed in the sub-Antarctic islands, along with changes in timing and patterns on the western Antarctic Peninsula (IPCC, 2007). However, prediction models suggest that there will be an average increase in annual precipitation of 18% in the Arctic and 14% for the Antarctic.

In both Polar Regions, an increase in temperatures and precipitation could result in an increase in the effective length of summers and warmer and more humid winters. Changes in temperature and precipitation could also have an impact on the physical environment, including particularly multi-year Arctic sea ice (see Box 7.1) and the glaciers of South Georgia, the Kerguelen Islands and Antarctic Peninsula (Convey 2006). The extent of multi-year Arctic sea ice in summer has already shrunk by 7.4% [5.0 to 9.8] per decade since 1978. In 2007, its area at the end of the summer reached an alarming record low, being some 40% smaller than during the same season in 1978. Some IPCC scenarios predict the complete disappearance of the Artic sea ice in the summer between now and the end of the century.

Table 8: Climate variations between now and the end of the century for Polar regions (IPCC, 2007).

Average for 21 global simulation models (scenario A1B). Margin of uncertainty in brackets (25/75% quartiles).

Climate indicator	Variation between 1980-1999 to 2080-2099
Air temperature	Arctic: Increase of 4.9°C [+4 to +5.6] Antarctic: Increase of 2.6°C [+2,3 to +3]
Precipitation	Arctic: Increase of 18% [+15% to +22%] Antarctic: Increase of 14% [+9% to +17%]
Artic Shelf	Arctic: Disappearance of the Arctic seasonal sea ice in summer

Impacts of climate change on biodiversity

Climate change could have an impact on the populations, behaviour and phenotypes of marine ecosystems as a whole. An increase in temperatures could, for instance, cause certain species to migrate towards the Poles. There could also be changes in reproduction and hunting zones (see Boxes 7.2 and 7.8), as well as in migration paths. The size and density of the populations are also likely to change, with a possible fragmentation and reduction in genetic diversity. Changes in the phenotypes of species would be a direct consequence of changes in environmental conditions: this could result in changes in dates of arrival of migratory species, nesting periods, breeding and egg-laying periods, etc. There will be behavioural changes among species requiring longer resting periods, longer cold periods, etc. Furthermore, changes in morphology, such as alterations in body mass or reproductive capacity, could take place due to energy constraints or changed physiological capacity (Trathan et al., 2007). Changes in conditions associated with Artic sea ice could affect both production of primary food species (see Box 7.5) and the higher predators that feed on them (see Box 7.6).

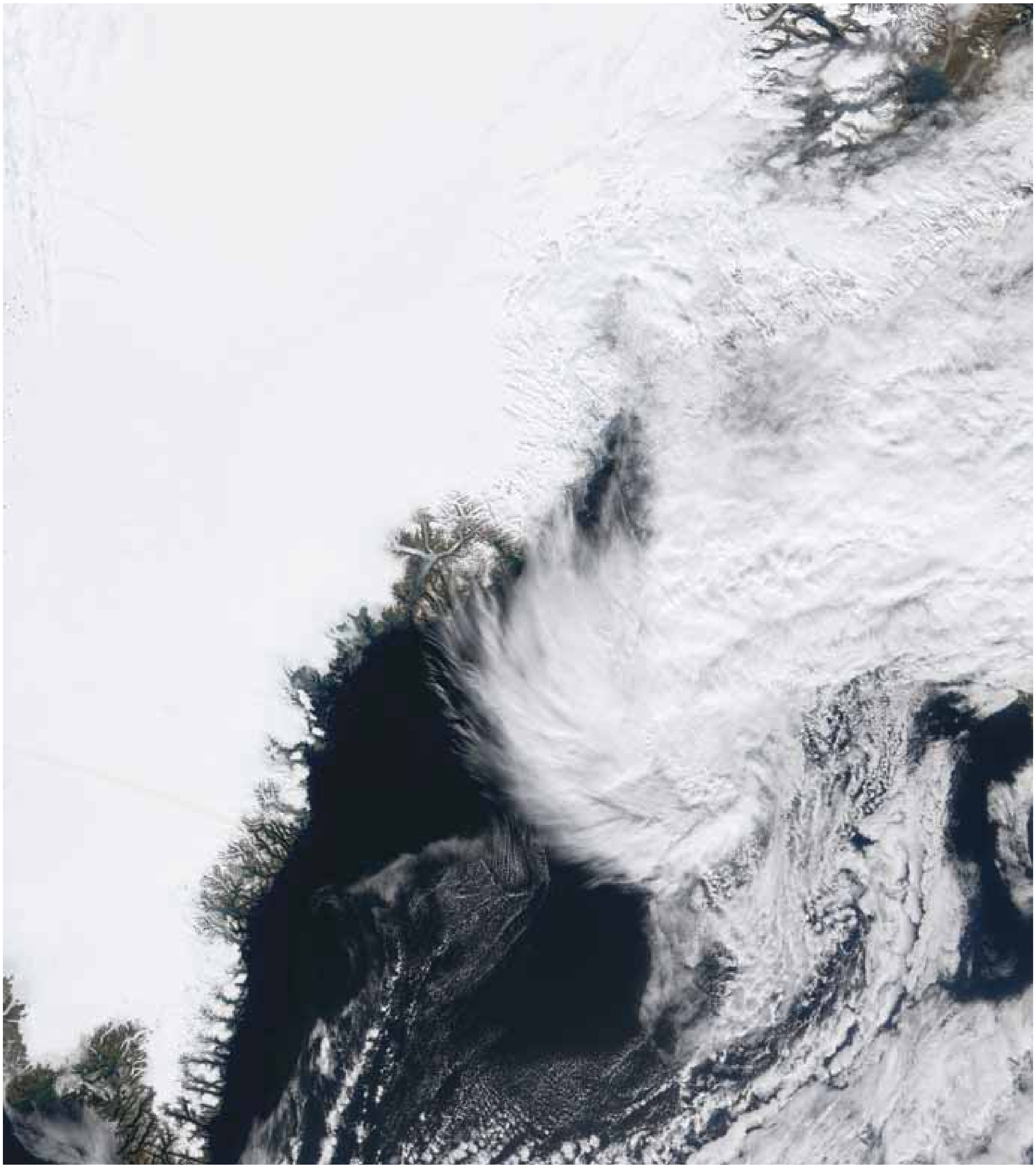
At the terrestrial level, some of the changes will be similar to those affecting the marine ecosystems. Migration of species towards higher latitudes is likely, particularly on land masses like Greenland. In southern Polar Regions such gradual changes in latitudinal range will be limited by the typically isolated nature of the islands and island-like exposure of terrestrial ecosystems (Bergstrom & Chown, 1999). Nevertheless, changes in the spatial distribution of species (native or alien), facilitated by human activity, are likely. The establishment and spread of invasive species will be further facilitated by milder climate conditions (see Box 7.7, Frenot et al., 2005). Some species have already begun to colonize larger areas of land spurred on by rising temperatures. This is the case, for example, of the Blue blowfly in the Kerguelen Islands. The retreat of the glaciers could also enable invasive species to colonize previously inaccessible areas. This is a growing threat on mainland South Georgia where impacts of rats on breeding birds (particularly burrow-nesting species) and overgrazing by reindeer could become more important in the future.

Socio-economic implications

Permanent human populations are far larger in the Artic territories (about 4 million inhabitants) than in the sub-Polar regions of Antarctica. As a consequence, the socio-economic implications of climate change on the local populations are likely to be more important in Greenland, for example. With the impacts of climate change on the Artic ice shelf and the ice cover, traditional hunting and fishing activities, which have already seriously declined, could be further compromised. Conversely, these impacts could have positive impacts for port access and maritime traffic in the region. In Saint Pierre and Miquelon, fishing activities have also been disrupted by changes in fishing quotas. A displacement of currently exploited fish stocks could result in a further transformation of this activity. In the sub-Antarctic islands, the main economic activity depends upon fishing permits. Thus, as in the Arctic regions, a change in the location, composition and size of the fish stocks, caused by a change in the spatial distribution of plankton, for example, could have serious consequences for fishing activities. With the exception of the Falkland

Geostock

Melting Arctic sea ice threatens Polar Beers


Nasaw

The Greenland icecap stores some 9% of global freshwater supplies

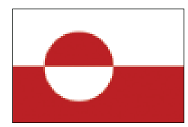
Islands (Malvinas), fishing activities are principally carried out for the benefit of populations outside the sub-Antarctic islands. However, revenue from fishing in South Georgia and the South Sandwich Islands is the main source of funding for environmental protection (including fishery protection) and research in that territory.

Responses to climate change

On the whole, the development of adaptation measures is still in its infancy, i.e., an understanding of the observed and potential impacts and identification of the stakes inherent to climate vulnerability. Climate change impacts in the Arctic have been assessed using an international approach, the Arctic Climate Impact Assessment (ACIA), which brought together all those countries with territories in the Arctic. Greenland is one of the territories involved in this initiative. This has enabled it to compare observed changes on its own territory with those in other parts of the Arctic world. A pan-Antarctic plan parallel to the ACIA is under development for initial submission to the Scientific Committee on Antarctic Research (SCAR) in July 2008. Deliberations on climate change and adaptation, similar to the Falkland Islands (Malvinas) Initiative, which led to the publication of the report *Global climate change in the Falkland Islands (Malvinas): predictions and solutions*, could then take place under a common framework involving all concerned countries.

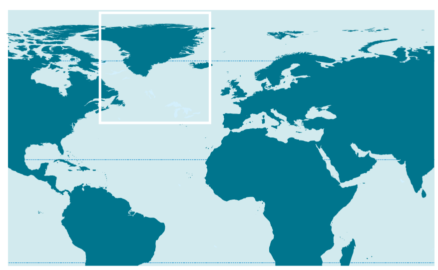
Martha de Jong-Lantink

Greenland



7.2 Autonomous province of Greenland (Danemark) PTOM

Number of islands:	1 island
Population:	56 344 inhabitants (2007)
Area:	2 166 086 km²
Population density:	0,026 inhabitants / km²
GDP/inhabitant:	30 000 $ / inhabitants (2005)
Unemployment rate:	6 % (2005)
Economic activities:	Fishing, fish processing, mining, tourism



Greenland is a Danish overseas territory situated in the North Atlantic, south of the Arctic Ocean. It is the largest island in the world. It is largely covered (80%) by an icecap, or inlandsis (see Box 7.1). Its highest point is Mount Gunnbjørn at 3,733 metres. Greenland has a very harsh climate with temperatures rarely rising out of negative figures for more than half the year. A large part of the territory is north of the Arctic Circle. During the summer, the temperatures become milder and the coasts green up again. The population of Greenland, which is concentrated in the coastal areas, is composed mainly of Inuits (about 85%) while the rest of the population being primarily Danes. Greenland gets most of its income from fishing and processing of fish products, mainly Greenland prawns (*Pandalus borealis*) and Greenland halibut (*Reinhardtius hippoglosoides*). Mining activities (diamonds, uranium, offshore oil, etc.) and tourism are up-and-coming and could become a significant source of income in the future.

7.2.1 Current state of biodiversity

Remarkable habitats and species

On the whole, the species which populate Greenland are adapted to the extreme conditions (sub-zero temperatures, extended periods of light and darkness, etc.). There are few endemic species in Greenland, although there is relatively high overall diversity (Jensen & Christensen, 2003). The reason for this is that most of the species that are present in Greenland today are currently thought to have come to the island at the end of the last ice age and are thus similar to those found throughout the rest of the Arctic. Moors and Arctic grasslands are the dominant terrestrial vegetation in Greenland. There are few herbivorous species, such as Reindeer (*Rangifer tarandus*), muskox (*Ovibus moschatus*) and Arctic hare (*Lepus arcticus*). Predators include the White-tailed eagle (Haliaeetus albicilla) for birds and, more rare, the Arctic wolf (*Canis lupus arctos*) for mammals.

The waters around Greenland are fairly rich in benthic fauna due to the fact that organic matter decomposes very slowly and is deposited in large quantities on the ocean floor. Further up the food chain, crustaceans are an important element of Greenland's marine ecosystems. Polar cod (*Boreogadus saida*) is also an important source of food for many species. The famous Blue whale (*Balaenoptera musculus*) and the Greenland Bowhead whale (*Balaena mysticetus)* feed exclusively on crustaceans and other planktonic organisms. Other baleen whales, such as Minke whale (*Balaenoptera acutorostrata*), fin whale (*Balaenoptera physalus*) and humpback whale (*Megaptera novaeangliae*) feed during summer months at high latituteds and supplement their crustacean diet with fish which reduces its dependence on the short plankton season. The narwhale (*Monodon monoceros*) a high Arctic toothed whale, feeds in deep waters on prey that include Greenland halibut (*Reinhardtius hippoglosoides*) and a variety of squid. The most common toothed whale in the Low Arctic Greenland is the harbour porpoise (*Phocoena phocoena*), which feeds on fish.The killer whale (*Orcinus orca*) prey upon fish and marine mammals, including seals, harbour porpoises and large whales. Seals are also the main prey of polar bear (*Ursus maritimus*). Among the pinnippeds, walruses (*Odobenus rosmarus*) feed mainly on a variety of shellfish, while true seals are mainly fish eaters, with exemption of the hooded seal (*Cystophora cristata*), which dives to deep oceanic waters to feed on fish and squid. Ringed seals (*Pusa hispida*), harp seals (*Pagophilus groenlandicus*) and bearded seals (*Erignathus barbatus*) are all aboundant. Greenland waters are important breeding and wintering areas for a large variety of sea birds, which feed on crustaceans and fish. Common species include little auk (*Alle alle*), brunnich guillemot (*Uria lomvia*) and several others.

Greenland is home to the largest national park in the world, which is situated in a sparsely-populated region and extends over some 956,000 km². In addition to this gigantic National park, there are nine further protected areas, included a Unesco World Heritage Site (The Icefjord of Ilullisat) and 11 Ramsar sites covering an area of 12,500 km². Fishing and hunting are extremely important activities in Greenland and concern over the sustainbalitity of some catches has lead to limitation in the takes of several species of birds (in 2001), narwhal and beluga (in 2004), polar bear (in 2005) and walrus (in 2006).

Current threats

Greenland's environment faces few direct threats from human activities, save for close to the towns and settlements. Only the south of Greenland is used for pasture and sheep. The development of tourist activities (particularly hiking), prospecting for and exploitation of raw materials present growing threats for the biodiversity. However, most threats to biodiversity are external and the result of pollutants on the one hand, and of climate change on the other hand (Biodiversity of Greenland).

7.2.2 New threats resulting from climate change

Global warming has been more pronounced in the Arctic than in most of the rest of the world; over the last few years the average temperature increase has been about 1°C per decade with a more marked increase in the winter and spring. This increase has already had serious impacts and affected the melting of the Arctic sea ice and the Greenland icecap as well as the sea of ice which surrounds the island (see Box 7.1). The IPCC predicts that average temperatures will rise by an additional 4.9° [+4° to +5.6°] between now and the end of the century.

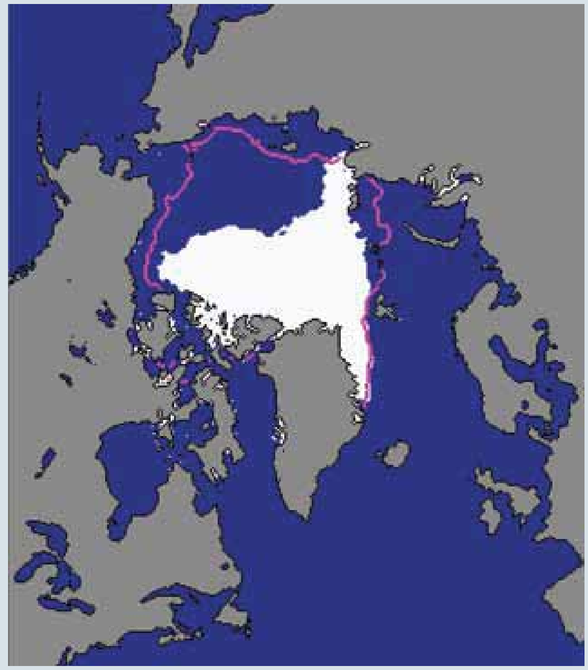
Martha de Jong-Lantink

Atlantic Walruses (*Odobenus rosmarus*)

Box 7.1: Melting of the Arctic Ice

The Arctic sea ice is melting markedly. The area of this floating mass of ice fluctuates on average between 7 million km² (at its smallest in September) and 15 million km² (at its largest in March). Over the last few decades, its minimum area has diminished significantly. In 1978, its recorded surface area was 7 million km², this had reduced to 5.32 million km² in 2005 and 4.13 million km² in September 2007 (NASA, 2007). In September 2007, its minimum surface area was some 40% lower than the seasonal average; this is the largest decrease ever recorded. These results exceeded all model forecasts presented by the IPCC for the same year. The Greenland icecap is also melting. Measuring 1,640,000 km², this icecap is the largest mass of ice in the Arctic and stores some 9% of global freshwater supplies. This icecap, which covers 85% of Greenland, is more than 3,500 metres thick in places. Recent aerial, satellite and seismic images have been put together to evaluate changes in the icecap: it is beginning to melt around the edges, because of increased rates of summer melt in the last 20 years. On the other hand, the centre of the icecap seems to be getting thicker, due to increased precipitation in this region. But this rate of increase is beginning to weaken. It is likely that in the future, the rate of melting will be far superior to the rate of accumulation and that the volume of the icecap will diminish significantly (ACIA).

Arctic warming will have indirect consequences for the entire planet. On the one hand, the melting of the icecap will have a significant impact on rising sea levels throughout the world. A complete thaw of the icecap, unlikely before several millennia, would raise sea levels by about seven metres (IPCC, 2001). A reduction in floating sea ice area, on the other hand will not lead to a significant rise in sea levels. However, the disappearance of this large reflective surface could result in greater local warming as a result of a drop in the albedo (surface reflexivity of the sun).



National Snow and Ice Data, Boulder, CO, Sept 2007

The Arctic sea ice in September 2007 (in white) was 40% lower than the average surface for this season (purple line)

Indeed, the absorption of the solar energy and its release into the atmosphere are more important and that contribute to contribute to enhance the local warming. Water absorbs far more energy than ice as ice reflects up to 80% of the sun's rays, while water only reflects 10% on average.

Impacts on biodiversity

With a change in climate, the dominant Greenland plant groups could migrate north and populations of rare or endemic species would diminish and their spatial distribution decrease, or in some extreme cases disappear altogether. Few plant species are likely to go entirely extinct in Greenland; the Sabine buttercup (Ranunculus sabinei) is one of the few species that could potentially disappear because of its limited spatial distribution. Indeed, it only grows in the narrow coastal areas in the north of Greenland. In the face of acute environmental competition, more "aggressive" species, like the birch, could take advantage of the alterations wrought by climate change and colonize new spaces. Changes in the composition of the plant populations, coupled with rising snow levels, would have dramatic consequences for caribous and Muskoxen. More regular alternating freeze/thaw periods would lead to a hardening of the snow cover and the formation of ice crusts; several species (Arctic hares, Lemmings, large herbivores, etc.) would find it more difficult to reach the vegetation beneath the snow. Most insect populations are likely to benefit from an increase in temperatures (ACIA).

A decrease the area of the Arctic sea ice extent is probably the most damaging impact of global warming for the marine ecosystems. The ice shelf provides an important habitat for several species, ranging from the micro-algae growing on the shelf to the marine mammals (it is both a breeding ground for seals and a hunting ground for polar bears). The shrinking of the shelf would have negative impacts on these species, some of which would be seriously affected. The Polar bear (Ursus maritimus) would be obliged to adopt a terrestrial lifestyle during the warmer months, which would result in a drop in the population, a potential cross-breeding with Grizzly bears (Ursus arctos horribilis) and Brown bears (Ursus arctos arctos) and growing interactions with human settlements (ACIA) (see Box 7.2). The edges of the shelf are also vital to the livelihoods of marine birds.

Socio-economic implications

Climate change will have a negative impact on the global fishing industry as a whole (UNEP, 2008). That said, in Greenland this sector may actually benefit. Shrinkage of the sea ice extent will facilitate access by fishing boats to the ports for longer periods. At the same time, an increase in water temperatures could give rise to a local increase in primary plankton production, and as a result lead to an increase in the fish stocks which depend upon this resource. This positive outcome could potentially lead to the further development of fishing activities which are currently Greenland's principal source of wealth.

Responses to climate change

Greenland is a member of the Arctic Council, the International Arctic Science Committee (IASC) and has participated in the Arctic Climate Impact Assessment (ACIA). All these activities

Box 7.2: The Lord of the Arctic in Danger

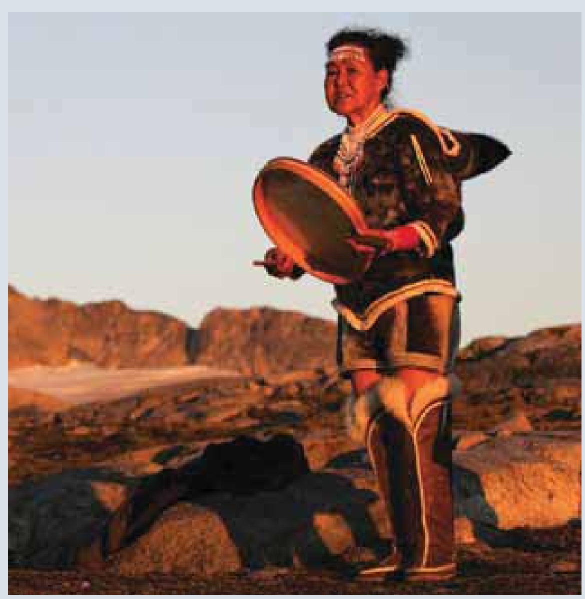
The Polar bear is an iconic Arctic species. This marine mammal is the largest land predator. Polar bears are found in all regions of the Arctic. The white bear, found on the Greenland coat of arms, is both an ambassador for the Polar Regions, but also, sadly, an ambassador for climate change. Indeed, climate change is having a very important impact on polar bear populations through one of its indirect effects: the shrinking of the sea ice area. The bears need ice to hunt the ringed seals and bearded seals which are their prey of choice. When the ice melts, the young bears survive on their stores of body fat for three to four months. The sea ice is melting earlier and earlier in the spring time and re-freezing later and later in the autumn. For example, in Hudson Bay (Great Canadian North), since 1985, the ice melt has advanced by two weeks and autumn freezing has been delayed by up to a week. A 2004 study showed that polar bears from the Great Canadian North lose an average of 10 kg of body fat for every week of delay. Thus, the bears of the Great Canadian North have lost an average of 80 kg between 1985 and 2004. The lack of body fat has serious consequences for female milk production because they do not feed while they are nursing. The belligerence of the bears is also affected: the hungrier the bear, the more likely it is to encroach upon settlements and become aggressive. Given the alarming rate with which the sea ice is beginning to deteriorate, the polar bear's hunting grounds are likely to be seriously compromised.

Polar Bear (*Ursus maritimus*)

have enabled Greenland to evaluate the impacts of climate change on its territory and to position itself in relation to the rest of the Arctic world. Impact evaluation is the first step in any process of adaptation to climate change. The population as a whole seems to have understood the climate threat; this has been demonstrated by the joint appeal by Greenland and French Polynesia to alert public opinion and decision makers to the "serious risk posed by climate change to their ecosystems and populations" (the appeal was launched by the Overseas Countries and Territories Association (OCTA) in Paris in 2006). An evaluation of the evolution of Greenland's animal and plant species will be necessary to truly appreciate the impacts of climate change. Monitoring polar bear and fish populations will be a vital step in order to best adapt hunting and fishing quotas.

Box 7.3: Impact on Traditional Societies in Greenland

The lives of indigenous people in the Arctic have already undergone significant changes in the last few decades because of their contact with the Western civilisation. A general decline in traditional life styles, and especially in diets, has brought with it new scourges such as tooth-decay, diabetes and cardio-vascular diseases. Climate change could lead to a decline in cold-related deaths and increase exposure of these populations to ultra-violet rays. However, it is above all traditional practices, such as hunting, that will be disrupted. Indigenous people have already begun to talk about nature's "unpredictability" which manifests itself through cracks in the sea ice and climate extremes to which these populations have been previously unaccustomed. For example, in 2001, indigenous people observed with alarm torrential downpours in the Thule region (North of Greenland) during the month of December. In 2002, the furthermost hunting grounds were still not covered by sea ice in January; only a few years previously, the hunters were used to seeking out their prey as early as October. In some areas the glaciers have retreated to such an extent that the local toponymy (scientific origin of place names) is no longer relevant. This is the case, for example, of Sermiarsussuaq (meaning "the smallest of the large glaciers") which has today disappeared (ACIA).



Nick Russill

Traditional Inuit culture

Steve Knowles and Susan Markanen

Saint Pierre and Miquelon

7.3 Saint Pierre and Miquelon (France) OCT

Number of main islands:	3
Population:	6.125 inhabitants (2006)
Area:	227 km²
Population density:	27 inhabitants / km²
GDP/inhabitant:	26 073 €/ inhabitants
Unemployment rate:	10 %
Economic activities:	Fishing

The Saint Pierre and Miquelon archipelago, in the North Atlantic, consists of eight islands, including three main islands: Saint-Pierre (26 km²), Miquelon (110 km²) and Langlade (91 km²); the latter are joined together by a low sandy spit. This archipelago is 25 kilometres south of the Canadian island of Newfoundland and close to the mouth of the Saint Lawrence River. Despite the fact that the archipelago is not located at high latitude, it experiences sub-Arctic oceanic conditions. Average annual temperatures hover around the 5,5°C mark, with 120 days of frost per year, and close to 80% humidity. Today, most of the population lives on the island of Saint-Pierre with 5.509 inhabitants in 2006. Saint Pierre and Miquelon's main economic activity is fishing (4,311 tonnes of fish were produced in 2004), especially cod fishing, fish processing and port activities. Tourism is a developing sector for the archipelago of Saint Pierre and Miquelon. A considerable proportion of the islands' income derives from subsidies and administrative budgets.

7.3.1 Current state of biodiversity

There are no endemic species in Saint Pierre and Miquelon because of its proximity to the North American continent. The archipelago has a variety of habitats: sandy beaches; dunes and coastal grasses; steep cliffs, which are a great favourite with the marine birds that use them as breeding grounds; sphagnum peatlands with ponds and marshes; and bare summits dominated by *Ericaceae* or heath plants. Finally, deep valleys carved out by water erosion, are covered by a natural boreal forest consisting conifers and other dwarf or creeping plant species, depending on their exposure to the wind. The flora consists of about

Mdf CC

Piping Plover (*Charadrius melodus melodus*), a near threatened species in North America

520 species of vascular plants of which at least 50% are aquatic and 27% have been introduced. As far as the bird life is concerned, one species has been introduced (the Ruffed grouse, *Bonasa umbellus*) and one species has disappeared (the Willow grouse, *Lagopus lagopus*). The population of marine nesting birds is of interest, particularly on Grand Colombier island, where more than 130 000 couples of Leach's Storm petrel (*Oceanodroma leucorhoa*) nest every year, as well as 10 000 couples of Atlantic puffin (*Fratercula arctica*), and the Common Mure (*Uria aalge*), the Razorbill (*Alca torda*), the Black Guillemot (*Cepphus grylle*) and the Black-legged Kittiwake (*Rissa tridactyla*). This site is currently promoted to become a National Natural Reserve. Several couples of Piping Plover (*Charadrius melodus melodus*), a near threatened species in North America, nest on the Miquelon-Langlade isthmus (IUCN Red List 2008). Indigenous mammals include the Meadow vole (*Microtus pennsylvanicus*), the red fox (*Vulpes vulpes*) and three species of bats. The Mountain hare (*Lepus timidus*), the Arctic hare (*Lepus arcticus*) and the White-tailed deer (*Odocoileus virginianus*) were introduced for hunting. They create an important grazing pressure on the boreal forest, eating sprouts and seedlings of deciduous trees and the Basalm Fir (*Abies balsamea*). Comparisons of aerial pictures of the Langlade island between 1952 and 2005 show a 37% reduction of the forest surface (Serge Muller, personnal communication 2008). Knowledge of the marine biodiversity is far more limited. The mixture created by the meeting of the cold waters of Labrador, the fresh water of the Saint Lawrence and the warm waters of the Gulf Stream has been highly beneficial to the development of plankton. This has attracted an important number of fish and significant numbers of marine mammals. The territorial waters are home to many of the same species found throughout the North Atlantic. Humpback whales (*Megaptera novaeangliae*) mix with Orcas and White-beaked dolphins (*Lagenorhynchus albirostris*). Large populations of Harbour seals (*Phoca vitulina*) and Grey seals (*Halichoerus grypus*) gather round the coastal areas. A biodiversity action plan is being implemented for the 2007-2010 period. On the whole, biodiversity is well conserved throughout much of the territory. However, anarchical urbanization, infrastructure development and unregulated circulation of off-road vehicles are beginning to cause soil erosion. This is all the more serious given that deforestation has been continuous since the arrival of the first fishing communities. The highly developed recreational hunting sector has also brought with it some serious problems. During the nesting season, the marine birds are disturbed by speed-boats and hunters. Over-fishing has led to abusive exploitation of fish stocks. (IUCN, Gargominy, 2003, 2007 Biodiversity Action Plan, Territorial Diagnosis, 2007).

7.3.2 New threats resulting from climate change

Impacts on biodiversity

Temperature increases in the area around Saint Pierre and Miquelon/Newfoundland could reach 2 to 3°C between now and the middle of the 21st century, in relation to 1960-1991 averages. Increases in annual rates of precipitation over the same period could be around 10% (Canadian Atlas of Climate Change). A monitoring network, observing the impacts of climate change on the arcto-alpine tundra, was implemented on 3 sites of the archipelago's submits, following the ITEX protocol (International Toundra Experiment) (Muller, personal communication 2008). Over the long term and as a result of a significant rise in sea level, the Miquelon-Langlade Isthmus could be partially submerged. This could also be the case of the Grand Baranchois lagoon (an important seal breeding site), the Miquelon basin, and even the Mirande pond. Overall, a rise in sea levels could result in erosion and deterioration of the coastal areas, particularly the sand dunes, the beaches and the coastal prairies. All these hypotheses need to be confirmed by sea level rise projections and submersion simulations for the territory. Invasive species, such as those already found on the archipelago, like the Japanese knotweed (*Fallopia japonica*), the Hawkweed (*Hieracium floribundum*) or the Common knapweed (*Centaurea nigra*), could benefit from better climate conditions and significantly extend their current spatial distribution.,

Andrew Johnson

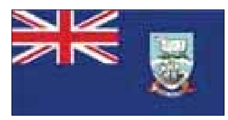
Arctic Hare (*Lepus arcticus*), an introduced species to the archipelago

Socio-economic implications

The fishing sector, which has suffered since quotas for the local fleet were reduced, is potentially the one that will suffer most from the impacts of climate change. Given the importance of this sector for the local economy, there is a need for in-depth studies to be undertaken. For example, the evolution of cod stocks presents a major strategic challenge. Agriculture could benefit slightly from increased temperatures given that at present it is a relatively poorly developed sector.

Ben Tubby

Falkland Islands (Malvinas)



7.4 Falkland Islands (Malvinas) (United Kingdom) OCT

Number of main islands:	2
Population:	3 140 inhabitants
Area:	12 173 km²
Population density:	0,3 inhabitants / km²
GDP/inhabitant:	25 000 $ / inhabitants
Unemployment rate:	0 %
Economic activities:	Fishing, agriculture

The Falkland Islands (Malvinas) are a United Kingdom overseas territory in the South Atlantic, situated 480 kilometres off the coast of South America and just north of the Antarctic Convergence (also known as the Antarctic Polar Frontal Zone). On the eastern island, Mount Usborne reaches an altitude of 705 metres. The territory consists of two main islands, the West Falkland Islands (Malvinas) and the East Falkland Islands (Malvinas), separated by the Falkland Islands (Malvinas) Sound and surrounded by about 700 islands and islets. The Falkland Islands (Malvinas) have a cold maritime climate with strong westerly winds. Precipitation is limited and more or less uniform throughout the year. Average annual temperatures are less than 10°C and rainfall averages about 625 mm/year. Prior to 1987, sheep farming and wool exports were the principal sources of income for the Falkland Islands (Malvinas). Since 1987, the sale of fishing licenses has become a new source of wealth for the islands. Oil prospecting activities recently resumed with the latest oil crisis. Tourism also accounts for a significant proportion of income.

7.4.1 Current state of biodiversity

The Falkland Islands‘ (Malvinas) vegetation is relatively poor. Most of the vegetation consists of maritime heath, acid grasslands, peatlands and coastal tussock grass. There are no native terrestrial mammals, amphibians, reptiles or trees. Insects make up the largest share of terrestrial ecosystem species in the Falkland Islands (Malvinas). The surrounding waters of the South Atlantic are very rich and support large populations of higher predators (birds and mammals) in the food chain. The archipelago is also a breeding ground for 70% of the world's Black-browed albatross population (*Thalassarche melanophrys*) and between a quarter and a third of the global Rockhopper penguin population (species *Eudyptes chrysocome chrysocome*). Among the many species found along the coasts, the Striated Caracara (*Phalcoboenus australis*, locally known as the "Johnny Rook"), a rare predatory bird, deserves a particular mention. This bird is only found in the Falkland Islands (Malvinas) and in some islands off the coast of Cape Horn. In terms of marine mammals, Southern elephant seals (*Mirounga leonina*), the Southern sea-lion (*Otaria flavescens*) and Southern fur-seal (*Arctocephalus australis*) also breed in the archipelago. In addition, fifteen or so species of whale and dolphin are also found in the waters around the Falkland Islands (Malvinas). The Falkland Islands' (Malvinas) government, private individuals and organizations (including Falkland Islands (Malvinas) Conservation and New Island Conservation Trust) manage nature reserves where they seek to preserve the biodiversity. In addition, since 1971, "Sea Lion" Island and Bertha's Beach have been designated Ramsar sites. Various mechanisms, including the 1999 Conservation of Wildlife and Nature Ordinance, the 1992 Mammal Protection Ordinance and an environmental charter signed in 2001, currently protect the biodiversity of this territory. Various environmental protection actors have also prepared an action plan for biodiversity conservation strategies to cover the 2006-2013 period. Direct pressure on the ecosystems is relatively limited in the Falkland Islands (Malvinas). However, fishing represents a potential threat to marine bird populations. Birds, particularly black-browed albatrosses and White-chinned petrels (*Procellaria aequinoctialis*), try to eat baited "long-line" hooks or are caught in the nets deployed by trawlers. Although the islands' fisheries licensing system provides a means of influencing the fishing practices of registered vessels in order to reduce these threats; the oceanic fisheries surrounding the Falkland Islands (Malvinas) (and those around the sub-Antarctic islands and across the region of CCAMLR management) are also subject to a considerable "illegal and unregulated" fishery pressure, involving vessels from many nations. Agricultural activities, particularly overgrazing by sheep, is a threat to plant communities in some parts of the Falkland Islands (Malvinas). The distribution of some plants can be reduced by up to 80 %, although no plant is thought to have gone extinct at present. As in other sub-Antarctic islands, invasive species also pose a threat to biodiversity (EU South Atlantic Environmental Profile).

7.4.2 New threats resulting from climate change

Climate changes have been observed close to the Falkland Islands (Malvinas). In particular, there has been a marked increase in sea water temperatures since the 1960s. Sea level data are available going back to the 1940s. An analysis of these data reveals that the sea has risen by an average of 0.7 mm/year compared with the global average of 1 to 2 mm/year. Scientists predict a cooling of the Falkland Islands (Malvinas) rather than a warming. However the sea surface temperature north of the Falkland Islands (Malvinas) (around the 40-50° latitude mark) might increase (Falkland Islands (Malvinas) Climate Change Report).

Impacts on terrestrial biodiversity

For the time being, little is known about the impacts of climate change on the terrestrial ecosystems of the Falkland Islands (Malvinas), not least because of a lack of baseline


Rita Willaert

Black- browed Albatross (*Thalassarche melanorphys*) diversity data. In order to remedy this, a programme supported by the University of Durham will shortly provide usable data to analyse the impacts of climate change on the terrestrial ecosystems of the Falkland Islands (Malvinas). Netherlands researchers, in collaboration with the British Antarctic Survey, have recently completed the first phase of environmental experiments aimed at modelling possible climate changes on the Falkland Islands (Malvinas) (e.g., Bokhorst et al., 2007). At present, the main source of worry in relation to climate change rests with invasive species. Numerous such species are present in the archipelago. The introduced Brown trout (*Salmo trutta morpha fario*) is already in fierce competition with the native Zebra trout (*Aplochiton zebra*); while rats and cats are the main predators of marine birds. They have, for example, contributed to a significant decrease in the number and range of the endemic passerine bird, the Cobb's wren (*Troglodytes cobbi*). Given that the Falkland Islands (Malvinas) could experience a cooling rather than a warming, the introduced species may be disadvantaged by the new climatic conditions. That said, however, the number of studies on the subject remains limited and the findings of these studies are not very clear (Falkland Islands (Malvinas) Climate Change Report).

Impacts on marine biodiversity

A worldwide study of marine mammals demonstrates that the precise impacts of climate change are as yet not well known for Sperm whales (*Physeter macrocephalus*), Sei whales (*Balaenoptera borealis*), Beaked whales, Peale's dolphins (*Lagenorhynchus australis*), Orcas (*Orcinus orca*), Long-finned pilot whales (*Globicephala melas*), Southern fur seals, South American sea lions and Southern elephant seals (Falkland Islands (Malvinas) Climate Change Report). However, based on current observations, there is strong reason to believe that most of these species will be negatively affected by a rise in temperatures and increased acidification of the ocean (which results from an increase in atmospheric CO_2 concentrations). Negative impacts are also expected to affect the populations of Commerson's dolphin (*Cephalorhynchus commersonii)* and Hourglass dolphins (*Lagenorhynchus cruciger*). Several species of whales, dolphins, and porpoises are already considered endangered or vulnerable. That said, however, given the limited data relating to the distribution and evolution of dolphin and whale populations in the waters around the Falkland Islands (Malvinas), it is difficult to truly evaluate the impacts of climate change on these marine mammals (Falkland Islands (Malvinas) Climate Change Report). There are however some data that can be put to good use. Falkland Islands (Malvinas) Conservation, for instance, has a database recording penguin numbers and breeding success that could be used in conjunction with oceanographic data. Although the success rate to date in the breeding of Thin-billed prion chicks in New Island has remained fairly constant despite temperature anomalies,


G Witzel

Commerson Dolphin *(Cephalorhynchus commersonii)*

it is possible that higher sea temperatures could result in lower rates of development and lower body masses among the young chicks. These two factors will have negative repercussions on the adult populations as well as on their capacity to reproduce (Quillfeldt et al., 2007).

Socio-economic implications

A rise in sea levels does not appear to pose a major threat in the short and medium terms, however, it could potentially prove a threat to coastal settlements in the long term. A change in storm activity in the South Atlantic could create problems; though building regulations in the Falkland Islands (Malvinas) currently impose a wind resistance threshold of 100 knots, which is well above the level of the 50 to 60 knot winds usually recorded in the archipelago. As far as fisheries are concerned, and given their importance in the islands' economy, any change in the distribution and abundance of exploited species could have strong impacts on this vital activity. But despite some hypotheses about the potential evolution of squids and other species, the impacts of climate change on this activity remain poorly understood (Falkland Islands (Malvinas) Climate Change Report).

Box 7.4: Communication about Climate Change from the Falkland Islands (Malvinas)

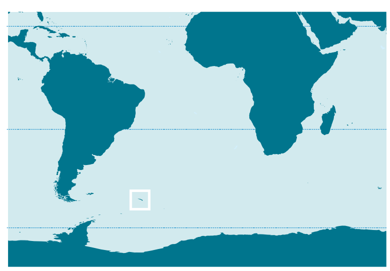
On 25 May 2007, the governor of the Falkland Islands (Malvinas) commissioned a report on the impacts of climate change in the archipelago. This report brought together members of associations, public administrations – including representatives from the departments of the environment, fisheries, agriculture, mineral resources and public works of the government of the Falkland Islands (Malvinas) – with members of Falkland Conservation and the New Island Conservation Trust. In addition to summarising the observed and potential impacts of climate change, this report also makes a series of recommendations for preparing the archipelago and developing a strategy for adaptation, as well as mitigation. These recommendations consist mainly of principles and directives to be followed rather than specific measures or concrete actions to be implemented. In view of the fact that the Falkland Islands (Malvinas)' scientific community does not have the resources necessary to undertake a modelling exercise of the local climate or to monitor the changes to the natural environments, external aid (especially British) will be vital to the realization of these objectives.

Wikipedia/Pismire

South Georgia and South Sandwich Islands

7.5 South Georgia and South Sandwich Islands (United Kingdom) OCT

Number of main islands:	8 (South Georgia, SG) 11 (South Sandwich, SS)
Population:	20
Area:	3755 km² (GS), 310 km² (SS)



South Georgia is situated in the South Atlantic approximately 1,400 kilometres to the east of the Falkland Islands (Malvinas). The South Sandwich Islands are approximately 700 kilometres south-east of South Georgia. Mainland South Georgia is 170 kilometres long and ranges in width from 2 to 40 kilometres; it has a very rugged landscape. The backbone of the island consists of two mountain chains with 11 peaks over 2,000; the high point of the island is Mount Paget at 2,934 metres. The maritime climate of South Georgia is particularly harsh, because of its topography and location, south of the Polar Front. The island is covered by several glaciers and snow fields. At sea level, maximum temperatures hover around 0°C in winter and 7.5°C in summer, average rates of precipitation reach 1,500 mm/year. The South Sandwich archipelago consists of several volcanic islands, most of which are still active; the climate is also extremely harsh. There are no permanent inhabitants on the islands of South Georgia and South Sandwich. The islands are home year round to temporary populations of scientists and a few passing tourists. Some 90% of the islands' incomes are derived from the sale of fishing licenses, which generate revenues of about 6 million Euros a year.

7.5.1 Current state of biodiversity

The vegetation of these islands is largely conditioned by the very harsh prevailing climate; there are no trees or bushes and the plant cover is similar to that found in Tierra del Fuego (Smith, 1984; Øvstedal & Smith, 2001). Mosses and lichens outnumber flowering plants. Tussock dominates the vascular plants. Of at least 70 higher plant species introduced to the islands, only 25 species have become established, although their diversity still outnumbers that of the native higher plants (Frenot et al., 2005). The vegetation of the South Sandwich Islands is even poorer because of harsher environmental conditions and volcanic activity (Convey et al., 2000). There is only a single species of vascular plant, the Antarctic hair grass (*Deschampsia antarctica*), which is also one of the two species found on the Antarctic Peninsula, and a limited range of mosses and lichens. However, the landscape does contain some extremely unusual ecosystems associated with geothermal activity (fumaroles, warm ground, etc.). There are no indigenous terrestrial mammals in South Georgia, although several species have been introduced. Only the reindeer, Brown rats (*Ratus norvegicus*) and House mouse (*Mus musculus*)

Cristopher

Chinstrap Penguin (*Pygoscelis antarcticus*) on South Sandwich Islands

have been able to adapt to the climate and have survived to the present day. Birds dominate the South Georgia vertebrate population, both in terms of number of species and total population. With several million individuals, this island is home to one of the most important populations of seabirds in the world. The island plays host to 11 species of albatross and petrel, of which seven are listed under the international Agreement for the Conservation of Albatrosses and Petrels (ACAP). This includes the largest breeding populations of the Grey-headed albatross (*Thalassarche chrysoite-chstoma*), Light-mantled sooty albatross (*Phoebetria palpebrata*), Northern giant petrel (*Macronectes halli*), White Chinned petrel (*Procellaria aequinoctialis*), Antarctic prion (*Pachyptila desolata*), and Common diving petrel (*Pelecanoides urinatrix*). South Georgia also hosts an endemic passerine, the South Georgia pipit (*Anthus antarcticus*). The South Sandwich Islands host significant bird populations, including the world's largest colony of Chinstrap penguins (*Pygoscelis antarcticus*) on Zavodovski Island and the northernmost breeding colonies of Adélie penguins (Convey et al., 1999). South Georgia is also the most important breeding location for Antarctic fur seals (*Arctocephalus gazella*). Among the toothed cetaceans that are found in the waters around South Georgia, there

cordyph

South American Fur Seal (*Arctocephalus australis*) in South Georgia

are Sperm whales (*Physeter macrocephalus*) and Orcas (*Orcinus orca*); there are also several baleen whales. Their numbers are becoming re-established, having been driven to the verge of extinction. The government of South Georgia and the South Sandwich Islands (GSGSSI) has extended the maritime zone from 12 to 200 nautical miles. No commercial fishing is permitted within the 12-mile zone of territorial waters. Long-line fishing is not permitted in waters shallower than a depth of 500 metres and bottom-trawling is not permitted throughout the 200-mile maritime zone. In addition, commercial fishing is prohibited in three designated areas of high benthic biodiversity. Incidental seabird and mammal mortality resulting from long-line fishing is nil and virtually nil (0.07 birds per trawl in 2006) in the pelagic trawl fisheries (Varty et al., 2008). The GSGSSI is considering designating the 12-nautical mile zone a nature reserve. The main threats to the biodiversity (excluding climate change) are accidental capture of marine species in fishing equipment outside the well-regulated fishery which takes place in South Georgia waters, and introduced species. Introduced species (like rats, *Ratus norvegicus*) prey upon eggs and chicks are a fairly major problem in South Georgia. In the coastal areas, which are overrun by rats, the South Georgia pipit (Anthus antarcticus) and smaller species of burrowing petrels have already been extirpated, while the populations of White-chinned petrels (*Procellaria aequinoctialis*) and South Georgia pintails (*Anas georgica*) have declined. The South Sandwich ecosystems on the other hand, are particularly well preserved thanks to difficult access and the absence of human settlements (EU South Atlantic Environmental Profile, SGSSI web site).

7.5.2 New threats resulting from climate change

There are approximately 160 glaciers on South Georgia. Of the 36 glaciers that have been studied using different technologies (ground survey, historical sources, satellite, aerial and oblique photographs), two are advancing, six are stable and 28 are in retreat. Glacial retreat, which has taken place since the 1980s, can reach several kilometres in some glaciers. It coincides with a succession of hot summers and global increases in temperatures. Glacial reaction depends on their type (for example, whether or not the glacier reaches the sea) and is relatively complex (Gordon, Haynes & Hubbard, 2007). Glacial retreat and an increase in temperatures could facilitate the colonization of previously inaccessible areas. A reduction in the seasonal sea ice coverage, particularly in the Scotia sea, could also lead to a decline in the krill population in the territorial waters. The krill population in the waters around South Georgia is particularly high; the south-west zone of the Atlantic contains over 50% of the krill stocks of the Southern Ocean. However, these populations have seriously declined in this region (Atkinson, 2004), indirectly affecting all the marine ecosystems (see Box 7.5). Ocean warming could have very important impacts on the marine invertebrates and fish by pushing their physiological attributes to the limit. Some species, which are highly specialized, could be forced to locate to colder waters because of their inability to adapt to rising temperatures.

NASA

28 of the 36 studied glaciers in South Georgia are in retreat

Box 7.5: Declining Krill

Southern Ocean populations of Antarctic krill (*Euphausia superba*), a crustacean at the bottom of the food chain, have declined between 38 and 75% in the south-west of the Southern Ocean since 1976 (Atkinson, 2004). The most likely explanation rests with the important reduction of the seasonal sea ice in this region, likely as a consequence of climate change. Krill feeds on microscopic algae which grow under the surface of the ice; the latter acting as a sort of nursery for juvenile krill. The Antarctic Peninsula, which has warmed up by 2.5°C in the last 50 years, has seen its seasonal surface area of sea ice dramatically reduced. With a drop in the ice coverage, resources available to the krill are believed to be reduced. A potential decrease in the abundance of krill, the bottom of the food chain, might have an impact on the marine ecosystems in the Polar Regions. Their decline could affect stocks of higher pelagic predators, marine mammals and seabirds that depend directly upon these resources (see Box 7.6). A similar phenomenon has also been observed in some areas of the Polar Regions of the northern hemisphere.

Øystein Paulsen

The krill is a small crustacean at the basis of the food chain in polar regions

Box 7.6: Blue Whales in Danger

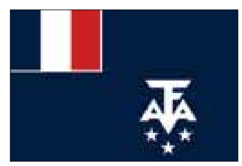
The Blue whale (Balaenoptera musculus), which occurs in the cold waters of the South Atlantic in the summer, is the largest animal on earth (20 to 34 metres long and weighing between 100 and 190 tonnes). This iconic species could be threatened by the indirect effects of climate change. Because of rising temperatures in the Antarctic Peninsula, the seasonal sea ice that surrounds the continent is beginning to show evidence of a reduction in some regions. This is threatening the populations of krill, the small marine crustaceans on which the Blue whale feeds during the summer feeding season (see Box 7.5). A team of researchers monitored the populations of krill predators in South Georgia from 1980 to 2000; the team observed periodic decreases in the size and reproductive capacity of all the species studied. The researchers concluded from this that the krill biomass was no longer sufficient to satisfy the needs of the region's cetaceans (Reid, 2001). Monitoring of higher predators continues on the island. Populations of Blue whales in the South Atlantic have been seriously depleted by commercial fishing and have gone from 250,000 specimens in the last century to approximately 1,000 today. Unlike some whales, the Blue whale has shown no clear sign of recovery since it was officially declared protected over 35 years ago (WWF, 2001). At the same time, illegal whaling by the Soviet Union, which continued until the 1990s, contributed markedly to the non-recovery of the whale population. Since the end of these illegal whaling activities, best estimates point to an increase of 7.3% per year but numbers remain at under 1% of their original levels (Branch, Matsuoka & Miyashita, 2004).

NOAA/Dan Shapiro

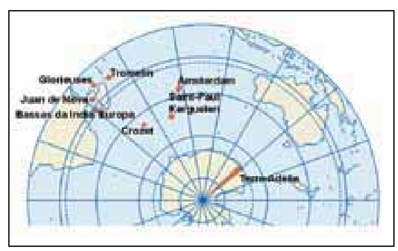
Blue Whale (*Balaenoptera musculus*)

UCN/Jean-Philippe Palasi

French Southern and Antarctic Territories



7.6 French Southern and Antarctic Territories (TAAF) (France) OCT



Number of islands:	1 (Amsterdam), 1 (Saint Paul), 5 (Crozet), 1 (Kerguelen)
Population:	No permanent inhabitants, scientific personnel
Area:	55 km² (Amsterdam), 6,5km² (Saint Paul), 355 km² (Crozet), 7 200 km² (Kerguelen),

Lost in the middle of the Indian Ocean, the islands of Saint-Paul and Amsterdam are among the most remote islands in the world. Of volcanic origin, their coasts are particularly jagged with cliffs rising to heights of between 30 and 700 metres. The two islands culminate respectively at 265 metres (Crête de Novarra) and 881 metres (Mont de la Dives). Further south, the Crozet Islands consist of two groups of islands of volcanic origin. To the east is the first group consisting of the Apostle Islets, Penguin Island and Pig Island; while to the west is the second group made up of East Island and Possession Island. The high point of the archipelago is Mount Marion Dufresne (1,050 metres). The volcanic Kerguelen archipelago consists of one main island, Grande Terre, and more than 3,000 islets. The coasts are very jagged and are interspersed with gulfs, bays and fjords. Mount Ross volcano is the high point of the island at 1,850 metres. The Cook icecap, with a total area of 550 km², partially covers the western parts of Grande Terre. The climate of Amsterdam and Saint-Paul is characterized by temperate oceanic conditions with frequent winds. Mean annual temperatures are between 12 and 14°C. The islands of Kerguelen and Crozet have a non-Polar cold ocean climate with mean monthly temperatures that never rise above 10°C and never fall below 0°C. The winds blow semi-permanently reaching speeds of 200 km/h. There are no permanent inhabitants on these islands, only scientists who come to conduct research. There are no economic activities on the TAAF islands. Fishing does, however, take place in the exclusive economic zone (EEZ). The regulations governing fishing are particularly strict with an annual quota designated according to strict scientific criteria and divided among fishing companies based on the Reunion Island. Most of the catch consists of the Patagonia toothfish (*Dissostichus eleginoides*), a highly coveted fish in the Asian markets. Philately also represents a source of income. Adélie Land forms a triangle in the east of the continent of Antarctica, between the 136ºE and 142º E lines of longitude, and culminates at the South Pole. Climate conditions are similar to those of the southern continent, characterized by very low temperatures (negative for most of the year, even at sea level), little precipitation and very violent winds (the highest winds ever registered at sea level with speeds of 320 km/h were recorded at the Dumont d'Urville base in 1972.).

7.6.1 Current state of biodiversity

Terrestrial biodiversity

The terrestrial biodiversity of these sub-Antarctic islands, while relatively limited in numbers (there are only 22 species of flowering plants on Kerguelen and 16 species on the islands of Crozet, (Frenot, Chapuis & Labouvier, 2001)), is nonetheless fairly rich for this environment. The rate of endemism can be high: for example, 55% of the invertebrate species of Crozet are endemic to this archipelago. The rate of endemism among the plants is much more limited; the Lyallia (*Lyallia kerguelensis*) is the only strictly endemic higher plant in the Kerguelen Islands. The Kerguelen cabbage (*Pringlea antiscorbutica*), an iconic species of the archipelago, is also found on the neighbouring islands of Heard, Crozet and Marion. Aside from the moss and the lichens, the islands' plant cover consists mainly of Acaena (*Acaena magellanica*), Azorelles (*Azorella selago*), ranunculae and seed plants. The only trees which break up this grassy landscape are the Island Cape Myrtle (*Phylica arborea*), found on the Island of Amsterdam. Among the native terrestrial vertebrates, only two species of birds are found on the island of Crozet and Kerguelen: the Eaton's pintail (*Anas eatoni*) and the Black-faced sheathbill (*Chionis minor*), both endemic sub-species to each of these archipelagos.

Marine biodiversity

The Kerguelen and Crozet archipelagos are close to the Antarctic Convergence where the cold waters of Antarctica meet the warmer waters of the Indian Ocean. This environment is singularly favourable to the growth of primary species, the first building block of the oceanic food chain. Thus, this zone is rich in pelagic species (crustaceans, squid, and fish). As a result, marine mammals and birds use these rich areas to feed and use the neighbouring islands to reproduce. Thus, there are important populations of Southern elephant seals (*Mirounga leonina*) in Kerguelen as well as Antarctic fur seals (*Arctocephalus gazella*) and Subantarctic fur seals (Arctocephalus tropicalis), also known as Amsterdam seals. This species is very abundant in the islands of Saint-Paul and Amsterdam. Among the cetaceans, the Commerson's dolphin (*Cephalorhynchus commersonii*) is found in the coastal waters of the Kerguelen Islands. But the greatest wealth of these sub-Antarctic islands, particularly the Crozet archipelago, rests in its marine bird populations (there are between 15 and 35 different species on these islands). Crozet is even nicknamed "25 million bird island". The density of the bird population reaches a staggering 60 tonnes/km². Among these species, penguins are very numerous with four dominant species: the King penguin (*Aptenodytes patagonicus*), the Gentoo penguin (*Pygoscelis papua*), the Southern rockhopper penguin (*Eudyptes chrysocome filholli*) and the Macaroni penguin (*Eudyptes chrysolophus*). Other marine bird species include petrels, albatrosses, prions, cormorants, skuas, gulls, terns, Cape petrels (*Daption capense*), etc. Amsterdam Island also has an important marine bird population with the largest colony of Atlantic yellow-nosed albatross (*Thalassarche chlororhynchos*) in the world and the only population of Amsterdam albatross (*Diomedea amsterdamensis*). If the Antarctic continent is something of a desert in terms of living species, the marine environment close to Adélie Land is conversely especially rich. There are large colonies of Adélie penguins (*Pygoscelis adeliae*) and Emperor penguins (*Aptenodytes forsteri*), the only marine birds found solely on the Antarctic continent and the Antarctic ice shelf.

Protected areas

Biodiversity protection was an early concern in these territories as witnessed by the designation of the Crozet Islands as "national park refuge for certain species of birds and mammals" as far back as 1938. Other protected areas were designated later, such as the White-chinned petrel (*Procellaria aequinoctialis*) colony in 1989. However, TAAF environmental protection policy turned a major corner in 2006 with the promulgation of Decree no. 2006-1211 of 3 October 2006 and the creation of the *Terres australes françaises* (Southern French Territories) nature reserve. Under this Decree, the islands of Saint-Paul and Amsterdam (including their domestic and territorial waters) were designated as national nature reserves, along with the Crozet archipelago territorial waters (excluding Possession Island territorial waters), and three zones of the Kerguelen Islands: zone 1 from Cape d'Estaing to Cape Cotter, zone 2 which includes the Nuageuses Islands, and zone 3 which includes the Railler du Baty peninsula. This decree also sets out the modalities for the management of this nature reserve and the regulations governing the terrestrial and marine areas as well as the strict protection zones. This nature reserve is the largest in France by surface area. As far as Antarctica is concerned, several laws and conventions protect the biodiversity of this continent, including the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), the Treaty of Washington, and the Madrid Protocol. In the light of all these various provisions, the whole of Adélie Land can be considered a protected area.

Current threats

Because of their oceanic origin and remote location, these islands have never been linked to continental masses and colonization processes were very slow. The food chains of the ecosystems are relatively simple and characterized by an absence of herbivores and carnivorous vertebrates. Thus, the terrestrial fauna and flora have never developed protective mechanisms against predators. As a result, the introduction of invasive species is the main threat to the biodiversity of the sub-Antarctic TAAF Islands (Frenot et al., 2005). Involuntary species introductions, such as Brown and Black rats (*Ratus ratus and R. norvegicus*), the House mouse (*Mus musculus*), flightless beetles (*Oopterus soledadinus*) or voluntary introductions like Rabbits (*Oryctolagus cuniculus*) and Cats (*Felis silvestris*), are exerting increasing pressure and strongly degrading the terrestrial ecosystems. Eradication programmes have been locally carried out to restore some of the islands degraded by these mammals. Some rare islands, like Penguin Island, as yet have no invasive species (Frenot et

IUCN/Jean-Philippe Palasi

Gentoo Penguin (*Pygoscelis papua*)

al., 2004). In Amsterdam, trampling by humans and more especially by animals as well as animal grazing, pave the way for the spread of invasive species and contribute to the degradation of the soils and increasing erosion. Tourism is not as yet a threat to the biodiversity of the TAAF because of the very limited number of visitors. The biodiversity of Adélie Land is not especially exposed to direct pressures.

7.6.2 New threats resulting from climate change

After a period of cooling in the 1960-1970s, average air temperatures increased in Kerguelen and in both the Amsterdam and Saint-Paul islands. These trends are similar to those observed in other sub-Antarctic islands such as Marion Island and Heard Island (Weimerskirch et al., 2003). At Port-aux-Français scientific base, there has been a change in climate conditions over the last few years. These have been characterized by a 1.3°C increase in temperatures since the 1960s and a drop in average precipitation levels of between 100 to 250 millimetres between 1994 and 2004 (Météo France). On Kergulen, the glaciers which rise from the Cook icecap have been in retreat since the end of the Little Ice Age (LIA – towards the mid-19th century). The Ampère glacial front, at the south of the icecap, for example, retreated by 1 kilometre between 1800 and 1970; this retreat has accelerated in the last few decades and the glacial front is today 3 kilometres from its position at the time of the LIA (Frenot et al., 1993). Between 1966 and 1977, this same glacier lost more than 150 metres of thickness (Vallon, 1977). Temperature observations recorded in Adélie Land are highly irregular and indicate gentle trends characterized by slight warming (which occurred later than in the sub-Antarctic islands) which evened out towards to mid-1980s and subsequently began to increase later on (Weimerskirch et al., 2003).

Impacts on terrestrial biodiversity

The impacts of climate change have found expression in a decrease in the coverage of native plant species (acanea, Kerguelen cabbage) caused by more frequent summer droughts over the last decade and the expansion of introduced fauna and flora which has been facilitated by rising temperatures (See Box 7.7).

Impact on Marine biodiversity

Between 1960 and 1995, the Amsterdam fur seal population increased markedly in Amsterdam, as did the population of King penguins on Possession Island. Conversely, the populations of Southern elephant seals decreased both on the islands of Kerguelen and Crozet, while the populations of Wandering albatross (*Diomedea exulans*) decreased and then increased again in Kerguelen and Crozet. Researchers have linked these fluctuations in the populations of these higher predators with a reduced availability of food further down the food chain. It would appear that there is a link between species fluctuation and changes in temperature, even though there is a temporal gap in the correlation between the increase in temperatures and a decrease in certain species. This gap can be explained by a reduction in fertility, rather than by a drop in the survival rate of adult specimens. It is interesting to note that most of the species that have declined are squid-eaters and, to a lesser extent, crustacean or fish predators; two species that have seen their numbers grow are consumers of fish (Myctophides). King penguins and Amsterdam Subantarctic fur seals could have benefited because they rely on a specific link in the food chain that is not significantly affected by changes in temperatures. But it is also possible that this improved situation is due in part to the recovery of populations following and end of excessive commercial exploitation (Weimerskirch et al., 2003).

Box 7.7: Climate Change and Invasive Species in Kerguelen

Most of the invasive species came to light after the establishment of the scientific bases, only a few arrived earlier with the whalers and seal hunters (Frenot, Chapuis & Lebouvier, 2001). At the plant level, 56 invasive species have been introduced to Amsterdam Island, 58 to Possession Island and 68 to Kerguelen. Among these species, some like dandelions (Taraxacum officinale), prairie flowers (,), the Birdeye pearlwort () or the Bog stitchwort () are considered invasive. All these invasive species are common to the temperate regions of the northern hemisphere and originated with European flora (Frenot et al., 2001). This phenomenon is not confined to plants, it has been observed in insects. The introduction of the Blue blowfly () in the 1970s was originally restricted to the heated buildings on the Port-aux-Français scientific base. However, increasingly mild climate conditions mean that today this winged insect is able to reproduce outside and spread to the eastern side of the Kerguelen archipelago. In these freshly colonized areas, the larvae of this introduced fly compete with those of a wingless indigenous fly () (IPEV). This wingless fly is also threatened by a predator, the Carabidae (), which arrived on the islands in 1913 in feedstock imported with sheep from the Falkland Islands (Malvinas). Carabidae populations appear to have increased in the last few years and according to researchers climate change could explain this demographic explosion (Renault & Lalouette, Univ Rennes 1). On Possession Island, a dandelion () and a Bog stitchwort () have already spread to the area surrounding the Alfred Faure base. This expansion remains much more limited than that of the dandelion in Kerguelen. A rise in temperatures could also enable these seed plants, whose numbers have remained constant over the last decade thanks to their asexual reproduction, to complete their reproductive cycle and considerably increase their power of dissemination (IPEV).

Jean-Louis Chapuis

The invasive dandelions (*Taraxacum officinale*) in Kerguelen

Box 7.8: King Penguins and Climate Change in Crozet

A study was recently undertaken of the King penguins (*Aptenodytes patagonicus*) on Possession Island in the Crozet archipelago, in order to analyse the correlations between the sea-surface water temperature, successful reproduction and the rate of adult survival. The King penguin is a very interesting species to observe because the chick-rearing period can last up to 13 months. This means that the chicks are still developing at the time when marine food resources are at their lowest levels and the food hard to access. It is during these periods that environmental changes, even minor, can have considerable impacts upon individual morphologies and more generally on the population as a whole. Researchers demonstrated that warm periods (linked to the warm El Niño cycles) had negative impacts both on the reproductive success and on the rate of survival of adults. Thus, all models suggest that an increase in temperature of 0.3°C can lead to a decrease of 9% in the survival rates of adult King penguins. This decrease is believed to be linked to a decrease in available food, which is itself linked to the primary production of phytoplankton and temperature ranges. The adults have to travel over greater distances in search of food. The young chicks are fed less frequently and the adults tend to favour their own survival rather than reproduce. A continued increase in the surface temperature of the ocean will pose a threat to populations of King penguins. Other marine bird species could also be affected by these mechanisms (Le Bohec et al., 2008). However, these results have been contested (Barbraud et al. 2008). Indeed, the study was performed on the survival of a group over a very short period (less than 10 years), while the king penguins at the Crozet Islands (and also Kerguelen Islands) have increased during the last 40 years (Delord et al. 2004, Weimerskirch et al. 2003) and the temperature of the ocean increased at the same time of more than a degree.

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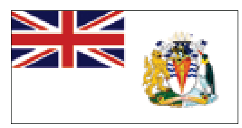
King Penguin (*Aptenodytes patagonicus*)

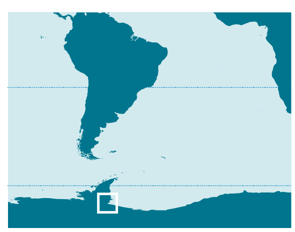
Rita Willaert

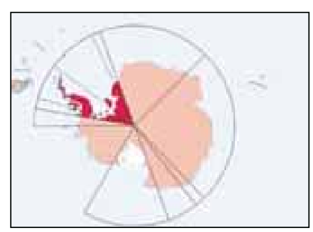
British Antarctic Territory



7.7 British Antarctic Territory (United Kingdom) OCT

Number of islands:	4 islands (South Orkney), 11 islands (South Shetlands)
Population:	No permanent inhabitants, scientists
Area:	1 709 400 km² (continent), 620 km² (South Orkney), 3 687 km² (South Shetlands)





The British Antarctic Territory includes all the lands and islands situated between 20°W and 80°W longitude and south of 60°S latitude. This group includes two archipelagos, the South Orkneys and the South Shetland Islands, part of the Antarctic Peninsula (including Graham Land, Ellsworth Land and Palmer Land), the Weddell Sea and the Ronne Ice Shelf. The South Orkneys consist of four main islands. The principal island is Coronation Island which peaks at 1,266 metres (Mount Nivea). The South Shetlands consist of 11 main islands; the high point is Mount Foster at 2,105 metres. The Antarctic Peninsula and the islands are mostly mountainous with significant ice cover (85% of the South Orkney Islands are ice covered). The climate conditions in these territories are extremely harsh with sub-zero temperatures along the Antarctic Peninsula throughout most of the year; conditions in the islands are more humid and slightly less severe.

7.7.1 Current state of biodiversity

Terrestrial biodiversity in these territories is very limited (Convey, 2007a); there are no terrestrial mammals or trees and only two flowering plants. The dominant plant cover consists of low-growing cryptograms including mosses, lichens, fungi and hepatic plants, found in those parts which are ice free during the summer months. The flowering plants include the Antarctic hair grass (*Deschampsia antarctica*) and Antarctic pearlwort (*Colobanthus quitensis*), the only indigenous flowering plants found in the Antarctic. Similarly, there are only two higher insect species. A wingless fly (the chironomid *Belgica antarctica*), which is endemic to the Antarctic Peninsula and South Shetland Islands, and another chironomid, *Parochlus steinenii*, which is Antarctica's only winged insect, occur on the South Shetland Islands, South Georgia and in Tierra del Fuego. The terrestrial fauna is dominated by some micro-arthropods that are mainly found in areas with vegetation. While diversity is low, in these locations population densities can be very high, and certainly comparable with those in temperate and tropical environments. In contrast with the land, marine diversity is particularly rich with several species of marine birds that forage in the near-shore and offshore waters and use the islands and exposed coastal rocks as nesting grounds. A very small number of species is suitably adapted to the climate conditions in the Antarctic to be able to breed, among them, the Emperor penguin (*Aptenodytes forsteri*), the Adélie penguin (*Pygoscelis adeliae*), the Antarctic prions (*Pachyptila desolata*) and the Snow petrel (*Pagodroma nivea*). Although penguins and petrels are the species most often associated with these territories, other Procellariidae (prions, fulmars and puffins) are also very abundant. Several species of whales and seals also take advantage of the fish and plankton-rich waters. The once heavily exploited whale populations are slowly growing again, however, several remain threatened, including the Blue whale (*Balaenoptera musculus*) and the Humpback whale (*Megaptera novaeangliae*). The absence of permanent inhabitants, both on the islands and on the continent of Antarctica, means that direct pressure on biodiversity is relatively limited. However, as in other regions, fishing poses a threat to seabirds, and particularly to albatrosses (British Antarctic Survey). Growing tourism is also an increasing threat to biodiversity, particularly the local flora. Tourism is largely restricted to the Antarctic Peninsula and the surrounding islands that play host to 98% of the visitors. Tourist numbers are rising significantly (there were some 13,600 visitors in 2001/2002 and over 35,000 in 2006/2007). Antarctic Treaty Parties and the International Association of Antarctica Tour Operators (IAATO) work closely together to promote safe and environmentally responsible tourism in Antarctica and have introduced a series of measures and guidelines to limit negative impacts. Tourist activities tend to be concentrated around the areas with the most interesting biodiversity, and where the need to protect wildlife and the vegetation is thus greatest (Frenot, 2007). In 1991 an Environmental Protocol to the Antarctic Treaty was adopted providing a framework for the comprehensive environmental protection of Antarctica. As a result, a whole series of protective mechanisms have been put in place to preserve the natural heritage of Antarctica by limiting as much as possible the impacts of the few human, scientific and tourist activities.

7.6.2 New threats resulting from climate change

The Antarctic Peninsula has experienced one of the highest rates of warming in the last 50 years, when compared with the rest of Antarctica or even the rest of the world (Turner et al., 2005). For example, the air temperature at Vernadsky Base has risen by 2.5°C. On the west coast, the rate of warming has been more limited in summer and spring than in winter and autumn, but the number of days with temperatures

Rita Willaert

Antarctic Skua (*Stercorarius skua*) in Port Lockroy above 0°C has risen by 74% (IPCC, 2007). These changes have not left the physical environments unscathed: the ice sheets have shrunk by more than 14,000 km² since 1974, 87% of the measured glaciers are retreating and seasonal snowfall has diminished (see Box 7.9).

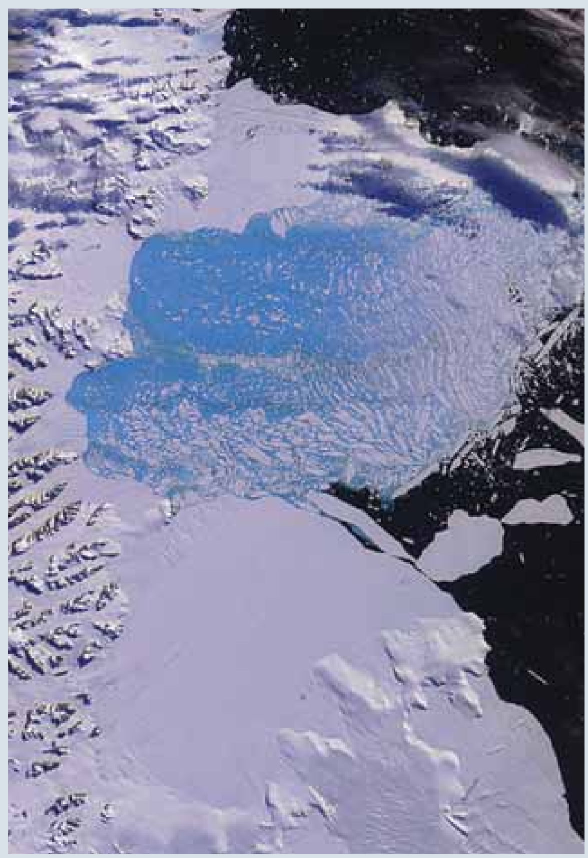
Rising air temperatures are almost certain to continue in the future and lead to ice and snow retreat, thereby paving the way for plants to grow. However, it is difficult to assess the direct impacts that climate change will have on the fauna and flora of the British Antarctic Territory because other influences are compounding this such as, for example, increasing exposure to ultra-violet rays (due to the hole in the ozone layer) and seasonal drought (Convey, 2006). Invasive alien species are also becoming a threat. Invasive alien species have already been observed in the sub-Antarctic islands and scientists are of the opinion that they could begin to make an appearance on the Antarctic Peninsula encouraged by both milder temperatures and increased human contact with the region (Frenot et al., 2005; Convey 2007c). Rising temperatures have also encouraged population increases and local spread of populations of native Antarctic hair grass and Antarctic pearlwort on the Peninsula.

It has already been explained above (see Box 7.5), that reductions in krill caused by increases in salps appear to be intimately linked to a decrease in the duration and surface area of sea ice. Recent research strongly suggests that if current rates of Southern Ocean acidification continue unabated, it is unlikely that pteropods (marine pelagic molluscs) will survive beyond 2100 (Orr et al. 2005 in IPCC, WGII, Ch.15). Deterioration of pteropod populations on this scale, a very important link in the marine food chain, would have potential consequences higher up the food chain. Continued acidification of the water would also have negative impacts on the cold-water corals. In the last few decades, scientists have observed a reduction in the population of krill, and the ice-dependent krill predator, the Adélie penguin, at the same time populations of the less ice-dependent krill predator, the chinstrap penguin (Pygoscelis antarcticus) have increased; however, these too are now decreasing in some areas.

The Antarctic Peninsula is therefore unique in its vulnerability to climate change, because of the intensity of the warming that has occurred. Long-term monitoring of the ecosystems and physical environments of the region are therefore paramount.

Box 7.9: Deterioration of the Ice Shelves and Substitution of the Fauna

The ice shelves are layers of floating ice which surround Antarctica and are fed by the continent's ice sheet and glaciers (some have a surface area stretching several thousand square kilometres). These ice platforms are diminishing in volume as a result of gradual ice melt around their edges, both at the surface and at greater depths; as they break up, they create icebergs. With the marked increase in temperatures on the Antarctic Peninsula (about 0.5°C per decade over the last 50 years), several ice shelves have partially or completely broken up. In 1995, Larsen A, an ice sheet 75 kilometres long and 37 kilometres wide, disintegrated in the Weddell Sea during a storm. During the southern summer of 2002, Larsen B, an ice sheet with a surface area of some 3,250 km² (or one and a half times the size of the Reunion Island) collapsed. More recently, in February 2008, at least 569 km² of the Wilkins ice sheet in the south-west of the Antarctic Peninsula disintegrated. The disintegration of parts of the glacial ice sheet is not without consequences for the fauna that live beneath them. A recent expedition carried out by the *Polarstern*, as part of the *Census of Antarctic Marine Life*, for the first time enabled scientists to explore the sea bed beneath the ice sheets, or rather, immediately after they had broken away. The fauna which live beneath these ice sheets tend to be similar to deep water or abyssal species because there is practically no light; furthermore, the few nutrients available are supplied through the lateral currents. A dramatic reduction in the area of the ice sheets allows light to penetrate the surface water layers and encourages the development of phytoplankton and zooplankton along with all the species that feed off them. For example, scientists aboard the Polarstern discovered large populations of ascidians or sea squirts that had colonized the sea bed after the collapse of Larsen B; along with sea sponges (*Hexactinellida*) whose populations were larger where Larsen A had once been than under Larsen B. Continued warming on the Antarctic Peninsula, which could well exceed current climate projections, will likely result in increasing collapse of the ice sheets in the future, and ice-dependent ecosystems will be required to evolve and adapt to new environmental conditions.



NASA Earth Observatory

Disintegration of the Larsen B plate in 2002

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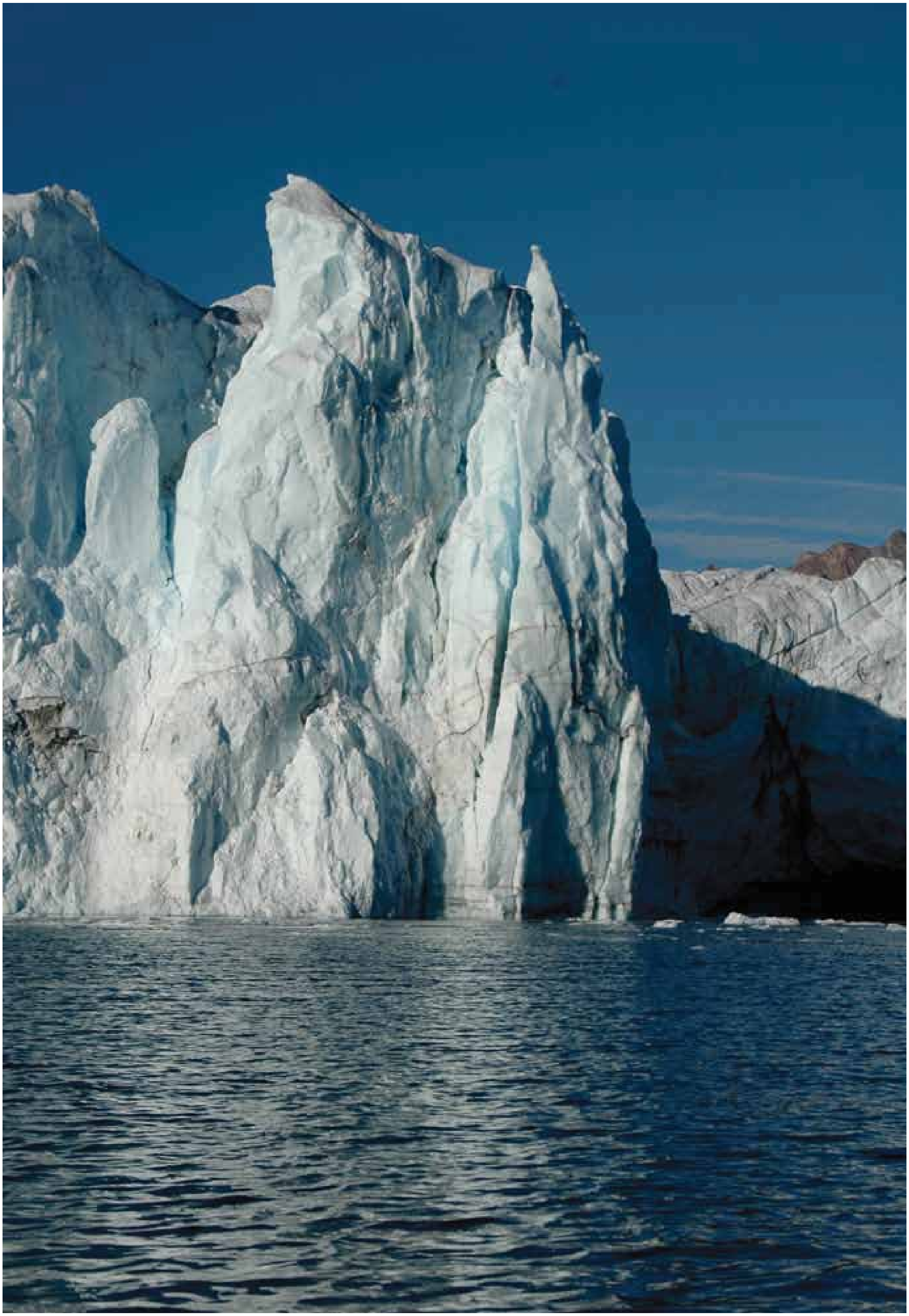


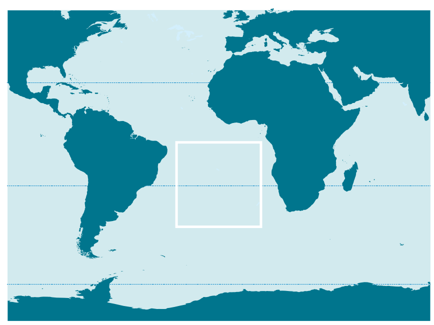
Eielson Glacier in Greenland

8. South Atlantic

Saint Helena, Tristan da Cunha and Ascension Island

8.1 Saint Helena, Tristan da Cunha and Ascension Island (United Kingdom) OCT

Number of islands:	1 for Saint Helena (SH), 1 for Ascension (A), 4 for Tristan da Cunha (TC)
Population:	5,157 inhabitants (SH), 1,122 inhabitants (A), 284 inhabitants (TC)
Area:	122 km² (SH), 97 km² (A), 201 km² (TC)
Population density:	42 inhabitants/km² (SH), 13 inhabitants/km² (A), 1.4 inhabitants/km² (TC)
GDP/inhabitant:	3500 € / inhabitant (2001)
Unemployment rate:	11,8 % (1998)
Economic activities:	Fishing



The British territory of Saint Helena consists of an administrative centre, the Island of Saint Helena, and two dependencies, Ascension Island and the Tristan da Cunha archipelago. These islands are in the South Atlantic, between Africa and South America. They are separated from one another by several thousand kilometres. In the north lies Ascension Island; Saint-Helena is located 1,300 kilometres to the south-east; while 2,400 kilometres to the south-west lies the Tristan da Cunha archipelago. The three islands are of volcanic origin; a major volcanic eruption took place on the island of Tristan da Cunha in 1961, leading to the total evacuation of the island.

The highest points of each territory are respectively Queen Mary's Peak for Tristan da Cunha (2,062 metres), Green Mountain for Ascension Island (859 metres), and Mount Acateon for Saint-Helena (818 metres). Because of the distance which separates them, and the differences in climate, fauna and flora, it is difficult to consider these territories as one whole. For this reason, this chapter has been divided into three parts.

Saint Helena is best known for having been the last place of residence of the Emperor Napoleon, after he was forced into exile and before his death in 1821. Economically, Saint Helena is dependent upon British aid, while Tristan da Cunha and Ascension are economically autonomous thanks to their fishing activities. Tourism is a minor industry, but there is a strong will to develop this activity, and there are plans to build an airport on Saint Helena to compensate for the poor sea links.

8.1.1 Current state of biodiversity

Remarkable habitats and species

The remoteness of these islands has resulted in a biodiversity characterized by a high level of endemism. For example, on the Island of Saint Helena, there are 45 endemic plants, 400 endemic invertebrates and more than a dozen endemic coastal fish species. Of the six species of endemic terrestrial birds that lived on the island before the arrival of humans, only the Saint Helena Plover (*Charadrius sanctaehelena*) has survived until today. In 2002, the last remaining (cultivated) specimen of Saint Helena Olive (*Nesiota elliptica*) disappeared.

The island of Ascension is also home to remarkable insular fauna and flora with 35 endemic species, including the Ascension Frigatebird (*Fregata aquila*). This species, like the Red-footed Booby (*Sula sula*), is especially threatened. The island is also home to one of the most important populations of breeding Green turtles (*Chelonia mydas*) in the world.

The Tristan archipelago supports five globally threatened seabirds including the vulnerable Spectacled petrel (*Procellaria conspicillata*), endemic to Inaccesible Island, and the endangered Atlantic yellow-nosed albatross (*Thallasarche chlororhynchos*). These islands are also home to four endemic land bird species, including the Tristan thrush (Nesocichla eremite) and the Inaccessible rail (*Atlantisia rogersi*), the world's smallest flightless bird. Both Inaccessible and Nightingale are almost pristine. The absence of human inhabitants means that there have been no human impacts on the vegetation, no introduced vertebrates, and relatively few impacts by invasive plants. The populations of Subantarctic fur seal (*Arctocephalus tropicalis*) and Southern elephant seal (*Mirounga leonina*), for their part, are slowly returning to the numbers they enjoyed prior to their intensive exploitation in the 19th century. Two endemic species of terrestrial birds, the Gough moorhen (*Gallinula nesiotis comeri*) and the Gough bunting (*Rowettia goughensis*), as well as 12 species of endemic plant can be found on the Island of Gough, further away to the south. The island's environment is near pristine thanks to a near total absence of introduced invasive plants. The House mouse (*Mus musculus*) is the only invasive vertebrate. There has been no human-induced modification of the vegetation. Gough Island is also one of the most important seabird islands in the world. It supports the entire global population of Tristan albatross (*Diomedea dabbenea*) and millions of pairs of other seabirds including the world's largest colony of Northern rockhopper penguins (*Eudyptes chyrosocome moseleyi*) and Dark mantled sooty albatross (*Phoepetria fusca*).

Current threats

DNumerous invasive species were introduced to the three territories both accidentally and deliberately. The introduction of rats and mice resulted in the disappearance of a large proportion of the indigenous bird life. Many seabirds have only survived on those islets and rocky outcrops that have not been infested by rats (*Ratus norvegicus and R. ratus*).

Saint Helena has lost three endemic seabirds and five endemic landbirds. The native vegetation has been destroyed in most places by a combination of soil erosion caused by over-grazing by introduced herbivores, and the spread of invasive plants.

In addition to millions of pairs of seabirds, Ascension Island for its part, has lost some common land bird species, the Dwarf bittern (Ixobrychus sturmii) and the Black-crowned night heron (*Nycticorax nycticorax*), the endemic Ascension rail (Atlantisia sp.) and in all likelihood an endemic night-heron. A very large proportion of the native vegetation has also been destroyed by Mexican thorn (*Prosopis juliflora*).

Tristan da Cunha has lost one endemic land bird and millions of seabirds of numerous species, but the other islands in the archipelago, and Gough, have been relatively little affected. However, it is now known that on Gough Island house mice now prey on seabird chicks, even those the size of large albatrosses, which is resulting in massive declines in this seabird community.

Alison Rothwell RSPB

Fishing boats in Tristan da Cunha

Illegal fishing, specifically by-catch by long-liners, and poor treatment of waste also pose a threat to the local biodiversity. Public administrations (such as the Ministry of Agriculture and Natural Resources) and NGO coalitions like the National Trust are working to protect the environment. Environmental policies, control mechanisms, and international cooperation are all contributing towards this objective. Furthermore, the Islands of Gough and Inaccessible have been listed as UNESCO World Heritage sites (Environmental Profile CE, UNESCO).

8.1.2 New threats resulting from climate change

Given the relatively limited territories in the South Atlantic, few observations and climate models are available. According to a 2003 study, there has not been any change in the levels of precipitation on the Island of Gough over the last 40 years (Jones et al., 2003). IPCC projections predict a rise in average temperatures of 2.5°C and a drop in average rainfall levels in the region, both in winter and in summer.

Impacts on biodiversity

Invasive species have already had a major impact on the biodiversity of many islands of the territory of Saint Helena. Mice, introduced to Gough Island, for example, have already decimated a large proportion of the Wandering albatross (*Diomedea exulans*) population as well as other marine birds (Glass, personal communication, Cuthbert & Hilton 2004; Wanless et al 2007). A change in climate could pave the way for greater establishment and spread by introduced species. Changes in sea level and ocean swell should not have an inordinate impact on the populations that currently nest in the coastal areas. It is possible that the Northern Rockhopper penguin or Subantarctic fur seal populations may be very slightly affected, although most of these species are used to constant changes in the coastal features (Ryan, personal communication).

Socio-economic implications

Little is known of the potential impacts of climate change on the fish stocks of Saint Helena, Ascension Island and Tristan da Cunha. The Tristan da Cunha archipelago is especially dependent on the local Tristan crayfish (*Jasus tristani*) and any change in the lobster population would be devastating for the archipelago's economy.

The prevailing conditions in the South Atlantic (water temperature, atmospheric conditions, etc.) mean that tropical storms do not tend to develop in that region of the world. That said, in 2004 a tropical storm developed for the first time in the South Atlantic and lashed the Brazilian coastline. In 2001, a strong storm resulted in serious material damage in the Tristan da Cunha archipelago, carrying off several roofs (made of asbestos) and damaging most of the islands' buildings. However, these isolated events do not make it possible to predict clearly that such extreme weather events will become the norm in the region in the future.

Furthermore, most of these territories are difficult to access, the sea is often rough and Saint Helena does not have sufficient port facilities. This is an obstacle to tourism development on the island (cruise companies tend to exclude the archipelago from traditional circuits) as well as for Tristan da Cunha's fishing and trade sectors. As a result, a potential change in the intensity of storms and ocean swell could be detrimental to the already minimal infrastructure and the current maritime routes (Personal communication, Essex, Glass and Ryan, EC Environmental Profile).

Mike Pienkowski

Ascension Frigatebird (*Fregata aquila*)

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8.2

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Conclusion

Given their geographic location and their unique environmental, economic and social characteristics, European Union overseas entities are especially vulnerable to the impacts of climate change. Coral bleaching, hurricane damage, rising sea levels, emergence of invasive alien species … from the tropics to the Poles, many impacts of climate change have been observed throughout the range of ecosystems found in overseas Europe. Observations on the ground are already a cause for concern. Future projections are at times disturbing. Climate change is rapidly emerging as a new threat to these ecosystems and the people leaving there, and is exacerbating already very serious existing pressures.

The impacts of climate change on biodiversity are often difficult to define with a high degree of certainty and hard to measure precisely. Projections for future changes and the reaction of species to these same changes are often unclear and in some cases remain simple hypotheses. Furthermore, it is often difficult to distinguish the effects of climate change from the impacts of other existing threats. However, the growing number of examples and the sheer extent of the ecosystems affected go some way towards helping us to evaluate the scale of possible effects. Their potential magnitude is becoming apparent and the adaptive measures needed to maintain the remarkable biodiversity of the overseas territories and ecosystems services require robust and urgent mobilization on the part of all concerned stakeholders.

An exceptionally fragile environment

The environment, structure and characteristics of the unique ecosystems of the European Union overseas entities make these territories particularly vulnerable to changes in climate. Often, these overseas territories are small, isolated islands with limited resources, which make them particularly fragile in the face of external stress. With a change in climate, their insularity and absence of continuous land mass prevent species from migrating in search of more clement conditions.

Island ecosystems are by nature fragile. The biodiversity of these often very specialized environments has evolved in isolation over several million years. In the absence of large predators, the food chains are limited. A disruption, even very minor, can have significant repercussions on the equilibrium as a whole. For example, introduced invasive species can spread like wildfire in the absence of predators or specific competitors. Similarly, coral reefs, which are home to the greatest portion of marine biodiversity, are fragile habitats that can decline rapidly with slight changes in the temperature or acidity of the water.

At the same time, overseas biodiversity is particularly remarkable. Many of the entities are situated in global "biodiversity hotspots". In the tropical islands, there are record rates of endemism, in sometimes very limited surface areas. A change in this biological heritage would represent a major loss for the entities concerned, but also for European, and even global, biodiversity as a whole.

Despite being particularly important, island ecosystems are also seriously degraded. Equally, the majority of recorded species extinctions have taken place on islands: invasive species, habitat destruction, overexploitation of resources, pollution… there are numerous drivers. These already severely degraded habitats are less resistant to external assaults. For example, it has already been widely demonstrated that the resilience of coral reefs that have already been weakened by pollution or over-fishing is much weaker than that of healthy reefs. Similarly, already seriously affected island ecosystems will have a much weaker resistance in the face of climate change.

In addition, hurricane-exposed tropical islands are particularly threatened by an increase in the number and intensity of these extreme weather events. Similarly, projections for global warming in the Polar Regions are almost twice as great as projections on the Equator. Overseas entities situated in the Polar Regions will have to withstand major climate variations with particularly strong repercussions.

These many examples clearly demonstrate that from the tropics to the Poles, the unique environments and ecosystems of the European Union overseas entities render them particularly vulnerable to climate change. These territories are among the first to experience the global changes that could eventually affect the entire planet.

A unique social and economic vulnerability

The unique social and economic characteristics of the overseas territories also make them particularly vulnerable to the effects of climate change.

Populations in the overseas territories often have a high density and are often concentrated in narrow coastal strips. The high altitude volcanic islands have a very mountainous and rugged terrain which makes it almost impossible for populations to migrate towards the interior to escape rising sea levels. The coral islands, for their part, are never more than a few metres above sea level, and are entirely dependent upon coral reefs to protect them from erosion. Island populations are therefore highly vulnerable to potential rises in sea levels.

Populations in the overseas entities tend to have more limited resources than their counterparts in continental Europe. As a general rule, the average GDP per overseas inhabitant is significantly lower than in Europe. Climate change will therefore affect poorer societies first, in part because of their limited capacity to adapt.

The economies of tropical islands are highly dependent upon natural resources. Industrial activities are, as a general rule, poorly developed and subsistence agriculture plays an important role in the informal economy. Fishing and agricultural activities also occupy an important place in the balance of trade. Pearl farming has become the primary economic activity in French Polynesia. A change in the state of the natural resources brought about by climate change could therefore have a particularly serious impact on the already fragile economies of these territories , where ecosystem degradation may lead to collapse of the economy.

Finally, tourism has become an important driver of the economy in most of the overseas entities. For many, it has become the most important economic pillar and the one offering the greatest potential for development, but at times represents also a major driver for ecosystem degradation. In the tropical islands, tourism is directly dependent upon the quality of the environment, especially the beaches and the coral reefs. A degradation of these features as a result of climate change could make these less attractive destinations and put a brake on economic development. The repeated destruction of tourist infrastructure by ever more intense cyclones and the emergence of new infectious tropical diseases are likewise phenomena that could lead to a reduction in tourist activity.

Fragile territories, indicators of climate change

Scattered throughout the four corners of the world, the overseas entities of the European Union are veritable indicators of the effects of climate change on the planet. Particularly vulnerable to environmental disturbances, they offer an early warning signal of the initial effects of variations in climate on a whole range of ecosystems, and hence indirectly on the populations that depend upon them. Just like "sentinel species" used in ecology (particularly vulnerable biomarkers used as evidence of the biological state of an area), overseas entities seem to be "sentinel territories" or beacons testifying to the effects of global changes on ecosystems and societies on a worldwide scale.

Particularly vulnerable to the impacts of climate change, overseas entities will need to develop robust strategies for adaptation. With the help of the international community, these regions could become centres of excellence for research on sustainable development, progress on renewable energies adaptation to climate change, conservation and sustainable use of biodiversity. They could develop and test new technologies and green infrastructures adapted to tropical regions, and become major partners for neighbouring islands or developing countries faced with the same challenges. Just like European Union ambassadors in tropical regions, they offer a very real opportunity for development and international cooperation.

A duty to act

Given that the islands are among the first regions to be affected by climate change, specific resources need to be made available to them in order for them to adapt. Because they fulfil a role as an indicator, a beacon for the effects of climate change, they require appropriate research activities to enable them to measure these impacts. Given that they can be pioneers for ecosystem management in the face of new threats, testing grounds to define and experiment with new strategies, they deserve special political consideration and adequate financial means. That said, overseas Europe is often overlooked in European political debates. The means available for the sustainable management of biodiversity are neither sufficient nor long-term. The biodiversity and climate change stakes are not sufficiently taken into account in the elaboration of local, national and European policies. Stakeholders concerned by ecological challenges in the entities are not sufficiently engaged in networks at the European level. Finally, the European overseas voice is not loud enough in national and international debates, or in biodiversity and climate change negotiations.

Given this reality, there is an urgent need for action. Any response to climate change needs to be based on an effective process of adaptation and mitigation and must involve all actors: the European Union, the concerned member states, the territories, but also associations, businesses, the media and civil society. This report presents a first evaluation of the impacts of climate change on the biodiversity of the overseas entities and the repercussions for the societies in these regions. It offers an overview of the threats and highlights the stakes for each territory. However, a territory-specific evaluation of each entity is required in order to properly define specific areas of vulnerability, and to put in place strategies for adaptation in collaboration with neighbouring territories, including also the reduction of other environmental pressures. Measures for adaptation and mitigation implemented by overseas Europe could serve as a model for the rest of Europe and the world; this would ensure that the specific vulnerability of the overseas territories in the face of climate change could become a strength and a driver of innovation.

The European Union and its Overseas Entities

Strategies to counter Climate Change and Biodiversity Loss

Message from Reunion Island

Message from the Conference "The European Union and its Overseas Entities: Strategies to counter Climate Change and Biodiversity Loss", Reunion Island, 7-11 July 2008

Introduction

The conference "The European Union and its Overseas Entities: Strategies to counter Climate Change and Biodiversity Loss" took place in Reunion island from 7 to 11 July 2008. It was an official event organized under the aegis of the French Presidency of the European Union.

In light of the increasing challenges presented by climate change and biodiversity loss, for the first time the conference brought together representatives from the EU's 7 Outermost Regions (ORs) and 21 Overseas Countries and Territories (OCTs). They were joined by delegates from EU Member States, European institutions, selected Small Island Developing States (SIDS), international and regional organizations, research institutes, civil society and the private sector.

The objectives of the conference were two-fold. On the one hand, the conference sought to raise awareness of the ecological wealth of the EU's overseas entities and of the threats facing them; and on the other hand, it sought to propose a European political strategy to respond to these threats through concrete action including adaptation to climate change, development of sustainable energy solutions, biodiversity conservation and ecosystem management.

The Message, adopted by conference participants, contains 21 proposals aimed at the ORs, the OCTs, and their regions of the world. It is strengthened by a portfolio of recommended actions and measures resulting from the 11 roundtables and workshops, in which more than 400 people participated.

Conference organized by:
International Union for Conservation of Nature (IUCN)
National Observatory on the Effects of Global Warming (ONERC)
Regional Council of Reunion Island
Ministry of Internal Affairs and Overseas and Territorial Collectives, France (now Ministry of Overseas, France)

Supported by:
Ministry of Foreign and European Affairs, France
Ministry of Environment, Energy, Sustainable Development and Spatial Planning, France (now Ministry of Ecology, Energy, Sustainable Development and Sea, France)

THE MESSAGE FROM REUNION ISLAND

Considering the exceptional importance of the biodiversity of the European Union's 7 Outermost Regions (ORs) and 21 Overseas Countries and Territories (OCTs) in comparison with continental Europe, and their vulnerability to climate change;

Considering also the importance of the social and cultural diversity of the 28 ORs and OCTs, and the fact that biodiversity provides many goods and services representing key assets for their sustainable economic development and the well-being of their populations;

Considering further the high degree of endemism and the fragility of the biodiversity found in the ORs and OCTs, in particular the threat posed by climate change and other, often interrelated, environmental factors such as invasive alien species (IAS), overexploitation of resources, pollution and habitat destruction;

Taking account also the socio-economic consequences and risks of these threats, and the need to provide environmental security to the human populations, especially but not exclusively, with regard to their food supply, health, well-being and protection against extreme weather events;

Considering that the maritime areas of the ORs and OCTs if taken together are the largest in the world;

Noting that the European Union and its Member States, who face many similar environmental threats, have an historic window of opportunity to value the unique assets and experience of the ORs and OCTs and make an important and positive impact on their biodiversity and sustainable development.

Taking into account:

- The European Commission's Communications of 26 May 2005 "A stronger partnership for the Outermost Regions", and of 12 September 2007 "Strategy for the Outermost Regions: achievements and future perspectives";
- The Blue Book "An Integrated Maritime Policy for the European Union" and its Action Plan, adopted by the European Commission on 10 October 2007;
- The Green Paper "Adapting to climate change in Europe – options for EU action", adopted by the European Commission in June 2007;
- The European Commission's Communication of 22 May 2006 entitled "Halting the loss of biodiversity by 2010 – and beyond", as well as the Council's Conclusions on the same subject of 18 December 2006;
- The final declaration of the OCTs at the OCT-EU Forum in Nuuk in 2006, at which they requested strengthened cooperation with the European Union in efforts to adapt to climate change and manage oceans and biodiversity;
- The «overseas territories» element of the "Message from Paris" on "Integrating Biodiversity into European Development Cooperation" approved by the "EU General Affairs and External Relations Council" on the proposal of the EU Finnish Presidency in December 2006;
- The Resolution on "European policy and biodiversity in overseas territories" adopted at the Third IUCN World Conservation Congress in Bangkok in 2004;
- The Global Island Partnership (GLISPA) launched under the Convention on Biological Diversity (CBD) at the 8th meeting of the Conference of Parties in Curitiba in 2006 and whose Strategy was adopted at the 9th CBD meeting in Bonn in May 2008, as well as the CBD Programmes of Work on Island Biodiversity, Marine and Coastal Biodiversity, and Protected Areas;
- Other recent decisions taken by the CBD Conference of Parties, such as those relating to climate change, invasive alien species, and protected areas.

The participants in the conference "The European Union and its Overseas Entities: Strategies to Counter Climate Change and Biodiversity Loss", held on Reunion Island from 7-11 July 2008:

Express their deep gratitude to the government authorities and the people of Reunion Island for their generous hospitality during the Conference. Moreover, they pay tribute to the pioneering efforts of Reunion Island in addressing the twin challenges of climate change and biodiversity loss, in particular through the creation of the Reunion Island National Park and by setting challenging targets in the fields of sustainable energy and clean transport;

Express their gratitude to the International Union for Conservation of Nature (IUCN), the Regional Council of Reunion Island, and the National Observatory on the Effects of Global Warming (ONERC) who have collaborated closely and effectively to deliver this first ground-breaking Conference bringing together all the EU ORs and OCTs, other island representatives, as well as EU Member States, European institutions, scientists, regional and international organizations, and civil society;

Express moreover their gratitude to the French Presidency of the European Union for its generous support of the Conference and for including it in its official agenda;

Recognize that biological and cultural diversity are essential for sustainable development at the global level;

Recognize moreover the unique character of the natural heritage of the EU's ORs and OCTs, as well as the threats facing this heritage and the sustainable development opportunities it offers;

Agree therefore on a set of recommendations, detailed in the Annex to this Message, and invite all OR and OCT stakeholders (the European institutions, all EU Member States and in particular the French, British, Dutch, Danish, Spanish and Portuguese governments, the OR and OCT authorities and other concerned organizations) to implement them, noting particularly that:

1. There is a need to continue raising awareness about the ORs and OCTs, especially at the European level, in relation to their particular situations, the risks they face and the opportunities they present.
2. Biodiversity loss and climate change cannot be addressed effectively unless the link between people, biodiversity and climate change is recognized. This requires the involvement of policy-makers, civil society, scientists, private sector and the general public. Targeted capacity-building tailored to the needs of the ORs and OCTs, in addition to significantly improved communication between the scientific community, civil society as well as policy and decision-makers are essential to develop appropriate responses. The challenges of climate change and biodiversity loss should be adequately integrated in the European Commission's "Strategy for the Outermost Regions" and the forthcoming Green Paper, "Future relations between the EU and the Overseas Countries and Territories".
3. The involvement of civil society in environmental decision-making in the ORs and OCTs requires a philosophical shift and new approaches, reflected in policy and practice at the European, regional, national and local levels. The technical capacity of local organizations must be enhanced and advocacy strengthened, and they should be given access to specially-designed funding mechanisms. Moreover public consultations should be made more transparent and accessible.
4. The ORs and OCTs should be used as out-posted observatories for global change phenomena and their impacts, including on biodiversity, as well as to research, pioneer and assess solutions in the context of sustainable development, including on ecosystem management, invasive alien species, energy, climate change adaptation and so forth.
5. More multi-disciplinary research in the ORs and OCTs should be promoted and funded with a particular focus on the linkages between climate change and human well-being and the role that biodiversity can play in the mitigation of and adaptation to climate change. A greater exchange of research between European countries and the ORs and OCTs should be facilitated, and the ORs and OCTs should be more effectively incorporated into EU Research Framework Programmes.
6. The ORs and OCTs should identify from within their own experience innovative actions aimed at tackling the related challenges of climate change and biodiversity loss, and should share their experience and best practice with the rest of the EU and with their regional neighbours.
7. The Member States concerned and the European Union should pay more attention to the specific challenges facing ORs and OCTs in international negotiations on climate change and biodiversity.
8. The EU, the ORs and OCTs, ACP countries and Small Island Developing States should unite in the face of climate change and biodiversity loss, by actively participating in international initiatives, such as the Global Island Partnership (GLISPA) and the CBD Programmes of Work on Island Biodiversity, Marine and Coastal Biodiversity, and Protected Areas.
9. Specific climate scenarios for each OR and OCT need to be developed, which should be supported by regional modelling; subsequently climate change vulnerability assessments need to be conducted and adaptation plans developed in all the ORs and OCTs, considering and involving the variety of relevant sectors, and adapting existing tools and methodologies. Finally, the proposed adaptation measures need to be implemented and monitored.
10. The EU and Member States should make stronger reference to the ORs and OCTs in the forthcoming European Commission's White Paper, "Adapting to climate change in Europe", and to the OCTs in the Global Climate

Change Alliance, particularly considering the impacts on biodiversity and socio-economies as well as the risk of environmental migrations.

11. All development projects should be assessed with regard to their social and environmental impacts, at the identification and evaluation stages, and incorporate mitigation and compensation schemes where necessary; funding should be conditional on compliance with this rule. Economic valuation is one (but not the only) important tool for influencing development strategies and decision-making. The profile of economic valuation needs to be raised and effective processes for the communication of results need to be developed. Tools should be appropriate for the specific situation of ORs and OCTs.
12. The quality and overall area of protected areas in the ORs and OCTs need to be increased to accommodate climate change impacts. The ecosystem approach should be applied outside protected areas, and the degree of threat from other direct drivers of biodiversity loss needs to be reduced.
13. There is an urgent need for EU Member States and the European Commission, together with the ORs and OCTs, to establish a voluntary scheme for the protection of species and habitats, inspired by the Natura 2000 approach. This scheme should be easily accessible, flexible, adapted to the local situation, balance conservation and development needs, as well as take into account existing mechanisms and tools. The implementation of the scheme should be based on local commitment and shared financing.
14. There is an urgent need to highlight the importance of species conservation, including outside protected areas. The priority should be given to globally threatened species, however locally threatened and/or endemic taxa should also receive due attention to reflect the particular vulnerability of island flora and fauna. The elaboration of restoration or management plans is only a first step in the process; it must be followed by effective implementation.
15. Networking among existing national parks and other protected areas is essential in order to harmonize monitoring, build capacity, exchange best practices and share data.
16. Currently, environmental funds earmarked for biodiversity conservation are insufficient. A specific fund for biodiversity should therefore be established to finance conservation action, field survey and monitoring work, as well as research on the economic value of biodiversity. Trust funds are needed to secure conservation measures in the long-term.
17. The environmental impact of invasive alien species tends to be much greater in the EU's ORs and OCTs than in continental Europe, resulting in substantial socio-economic risks and a disproportionately high impact on wider European biodiversity. Campaigns to change awareness and attitudes of public and private decision-makers at all levels are fundamental to improving prevention and management policies. The ORs and OCTs should be fully integrated into the future EU Strategy on Invasive Alien Species, and the consistency of other Community policies and actions enhanced. IAS strategies that build on IAS inventories, monitoring and early warning systems should be developed in each OR and OCT.
18. The vast marine and coastal areas of the ORs and OCTs provide the EU and its Member States with an array of remarkable and sometimes unique ecosystems, fisheries resources and emblematic species. They deserve to be part of a long-term strategic vision that integrates bio-geographic aspects, requiring special attention in EU funding mechanisms and policies, in particular the Maritime Policy, in order to address the manifold anthropogenic stresses such as over-exploitation and pollution. Suitable monitoring of the marine environment on the basis of a coherent European-wide database is essential for the sustainable management of natural resources and the development of climate change adaptation strategies. The listing and protection of key marine sites, regionally mainstreamed Integrated Coastal Zone Management, fisheries stock assessments, as well as enhanced control and management of legal and illegal fishing activities are further critical elements.
19. The EU and its Member States should consider energy policies as a major component in the fight against climate change in the ORs and OCTs as well as in their neighbouring regions. Taking into account differences in population levels and socio-economic activities, strategies for energy autonomy should be developed for each territory based on sustainable energy consumption, significantly reduced greenhouse gas emissions, and zero direct negative impact on biodiversity. Each territory should seek to develop an energy mix which includes energy management, development of renewable energies and their storage, and mainstreaming of sustainable energy into urban planning. Specific tools should be deployed to build capacity and mobilize stakeholders in the ORs and OCTs, most importantly through energy agencies, private sector companies, training and R&D facilities, as well as specially adapted legal and fiscal tools. In this context, intra-regional networking to share best practices and conduct joint activities is critical.
20. Regional cooperation is now recognized by all actors as both an opportunity and a responsibility. Many of the issues related to biodiversity and climate change are more effectively treated at a regional level; regional cooperation can create many opportunities (co-development, exchange of best practice, sharing of skills and resources, economies of scale, synergies, etc.) while also increasing the voice of ORs and OCTs at a global level. The EU, including as appropriate, the Member States, the ORs and OCTs, and relevant international organizations should therefore continue to strengthen their involvement in regional cooperation efforts. Policies and practices should facilitate and support such cooperation between the ORs, the OCTs and their neighbours through appropriate legal frameworks, by improving information exchange as well as enhancing the role of existing regional structures and global institutions.
21. Action should be taken urgently towards the development of a network of stakeholders, in order to reinforce the linkages and offer opportunities for exchange between the different actors working on the ORs and OCTs. Moreover, the creation of such a network would allow the promotion of knowledge about already existing policies and financial mechanisms, the fostering of thematic initiatives at the scale of all ORs and OCTs, and the implementation of the Message from Reunion Island. As several successful platforms exist, a value-added mechanism must be identified that optimizes overall effectiveness.

RECOMMENDATIONS

A. How should we adapt to climate change, increase the resilience of ecosystems and reduce the vulnerability of human cultures and activities?

Cross-cutting issues

1. Develop specific climate scenarios for each OR and OCT, supported by regional modelling and building on EU-backed research programmes where appropriate. These should identify the threats posed by climate change and allow for appropriate adaptation measures.
2. Improve representation of ORs and OCTs in relevant international and regional fora (e.g. UNFCCC and other MEAs, including regional preparatory meetings) and enhance access to global, EU and/or regional financing mechanisms.
3. Raise awareness about the ORs and OCTs, where applicable and appropriate.
4. Strengthen science-to-policy communication and build awareness among decision-makers, the private sector and the general public.
5. Promote «win-win-win» solutions (that achieve simultaneously mitigation, adaptation and biodiversity conservation).
6. Consider establishing specific funding streams at the European Commission to address environmental challenges in the OCTs, to avoid them having to use limited development funding (i.e. under the European Development Fund) for this purpose.

Adaptation planning and related policy recommendations

1. Enhance the capacity of OR and OCT governments, particularly in relation to personnel and financial means, to recognize and respond firmly to the challenge of climate change.
2. Conduct climate change vulnerability assessments and adaptation plans in all the ORs and OCTs, considering and involving the variety of relevant sectors; adapting existing tools and methodologies such as those of the UNFCCC (e.g. National Communications on Climate Change, National Action Plans for Adaptation; with the possible inclusion as special annexes to the reports of the respective Member States); subsequently implement and monitor these adaptation measures.
3. Take into account the impact on biodiversity and ecosystem services of all mitigation and adaptation planning and interventions, using cost/benefit analyses, longer-term environmental impact assessments (20-50 years), and holistic approaches that integrate and balance environmental, social and economic/development aspects.
4. Promote voluntary coastal-zone management programmes for adaptation to climate change as a tool to build ecosystem resilience, protect ecosystem services and secure local livelihoods.
5. Promote a stronger reference to, or inclusion of, the ORs and OCTs in the European Commission's White Paper on Climate Change Adaptation (DG Environment), and of the OCTs in the Global Climate Change Alliance (DG Development); given that the latter currently focuses on climate change adaptation in Small Island Developing States and Least Developed Countries, and in view of the limited resources allocated, increase the financial resources by an order of magnitude to allow their inclusion.
6. Place greater and more numerous areas (including more environmentally diverse protected areas and altitudinal gradients) under conservation regimes to achieve the same level of biodiversity conservation over the long term; apply the ecosystem approach outside protected areas and reduce the degree of threat from other direct drivers (pollution, over exploitation, habitat loss, invasive alien species [IAS]).

Research and monitoring

1. Enhance and coordinate high-quality research across institutions, and monitor the impact of climate change on the ORs and OCTs, avoiding duplication and improving cataloguing systems, promoting the open sharing of data and resources, and the availability of long-term data sets (e.g. via the EU-Joint Research Centre); consider the establishment of an ambitious research and knowledge facility and local and regional programmes on climate change and biodiversity.
2. Improve integration of sectoral information sources for climate research including data from offshore monitoring stations and satellites, and expanding island-based pilot projects.
3. Expedite research and ensure effective dissemination and implementation of research findings.
4. Integrate traditional and local knowledge with scientific research and promote community participation and engagement in local monitoring.

Regional cooperation

1. Promote long-term strategic planning and alignment of priorities between and within regions, building on the work of existing regional organizations where possible.
2. Prioritize improved coordination in the following areas: biodiversity, forestry, tourism, coastal management (including sea-level rise), marine and coral reef management, fisheries, sustainable energy, food security and disease control.

B. Economic assessment of ecosystem biodiversity and services: what role does it play in development strategies?

Recommendations

1. Integrate the economic valuation of biodiversity and ecosystem services into the assessment of all development projects, programmes and policies affecting the ORs and OCTs.
2. Use pragmatic, practical techniques appropriate to OR and OCT conditions for economic valuation and assessment at project and programme levels.
3. Contribute to international environmental economics exercises (e.g. the second stage of the study on The Economics of Ecosystems and Biodiversity [TEEB]).
4. Improve communication to, and among, stakeholders and decision-makers, highlighting the linkages between poverty, biodiversity, ecosystem services and climate change, including the need to integrate biodiversity considerations into the development-aid process and, where appropriate, National Poverty Reduction Strategies and Plans (NPRS).
5. Ensure good scientific research data are collected, including by governments, and integrated into geo-referenced databases that link socio-economic data and ecological data.
6. Offer training and networking opportunities tailored to the needs of the ORs and OCTs, in particular for those islands and other countries with limited capacity; networking should be predominantly promoted among ORs and OCTs and other islands and territories within their regions, which share similar challenges.
7. Coordinate with other partners, in particular international financial institutions (such as the World Bank and other Regional Development Banks) to ensure the inclusion of biodiversity considerations in projects and programmes funded for the benefit of small islands.

Specific projects

1. Evaluate options for compensating losses of biodiversity and ecosystem services resulting from development projects. Outputs of the study may be used as material to support the development of a new EU regulation.
2. Establish regional pilot projects in ORs and OCTs to build capacity in the use of economic valuation and assessment, and their incorporation in natural resource and biodiversity policy and decision-making. In particular, pilot projects should involve economic valuation of watersheds, coral reefs, mangroves, forests and other ecosystems, as well as assessment of the economic impact of invasive species and unsustainable natural resource management practices. The pilot projects will develop methodologies and training activities and enable transfer of lessons learnt to other islands and regions. The projects will also assess the feasibility of using benefit-transfer techniques as part of the development of best practices in economic valuation and assessment.

C. Which strategies should be adopted to deal with invasive alien species (IAS)?

Recommendations to all stakeholders

1. Raising awareness and changing attitudes of decision-makers at EU, national and local levels, industry and commercial stakeholders, and the public is fundamental to tackling IAS problems in the ORs and OCTs. Targeted communication campaigns need to demonstrate how IAS prevention and control are integral parts of biodiversity conservation and bring lasting benefits to communities and the economy by safeguarding ecosystem services and functions.
2. Strengthening inter-regional and intra-regional cooperation and capacity is essential for timely and cost-effective action. Where possible, this should build on existing regional mechanisms and practical tools such as those developed by the Global Invasive Species Programme. Information sharing to anticipate new threats, alert neighbouring territories of new incursions and provide technical support should be seen as a key element of EU and regional solidarity.
3. Comprehensive prevention policies for ORs and OCTs should be aligned with legislation on external trade and internal market regulations, and cover imports, exports, management of introduction pathways (including trade, shipping and aviation) and internal introductions (including inter-island and mainland-island movements).

Specific recommendations addressed to the European Commission

1. Fully integrate the ORs and OCTs in the future EU Strategy on Invasive Alien Species and ensure coordination and consistency across all applicable Community policies and actions.
2. For the ORs, urgently develop strict legal measures consistent with Article 30 of the Treaty to prevent IAS introductions damaging to island biodiversity (e.g. through use of adapted species-listing techniques).
3. Support the development of interlinked IAS inventories, monitoring and early warning systems in all ORs and OCTs, building on precedents such as DAISIE (Developing Alien Invasive Species Inventories for Europe) and covering terrestrial, freshwater and marine ecosystems.
4. Support coordinated research to inform planning and decision-making (e.g. risk analysis that includes consideration of climate change, application of environmental economic analysis to activities involving risk of introduction or spread of IAS, cost-benefit analysis to identify IAS control programmes that deliver maximum conservation benefit for minimum cost).
5. Mainstream IAS considerations into all relevant funding mechanisms: in particular, strengthen financial support for IAS prevention, rapid response and longer-term control and restoration programmes, and enable funding of programmes covering whole bio-geographic regions (which could include non-EU countries or territories).

Specific recommendations addressed to Member States and local administrations

1. Develop an IAS strategy for each OR and OCT, supported by cross-sectoral coordination arrangements and full stakeholder involvement.
2. Strengthen the legal framework, human resources and associated equipment and infrastructure necessary to ensure effective border control, including taxonomic capacity.
3. Integrate measures to enhance ecosystem resilience into sectoral plans and instruments that impact on terrestrial and aquatic ecosystems, avoiding the use in landscaping and other land-management programmes of species known to be invasive in similar environments.
4. Prioritize the amendment or development of legislation to provide a strong legal basis for eradication or control of existing IAS, including feral animal populations and stray animals, and develop collaborative procedures and information materials to address conflicts of interest.
5. Take urgent steps to (re)create sanctuaries for threatened species in small islands where it is still considered feasible to eradicate introduced animals and plants to safeguard globally unique biodiversity.

D. How should the role of civil society in environmental issues in the ORs and OCTs be strengthened?

Recommendations to the EU and national agencies

1. Strengthen and expand the participation of civil society in European policy and decision-making processes.
2. Design EU funding mechanisms and information strategies that are accessible to a wider range of civil society organizations in the ORs, OCTs and SIDS and respond better to the need for long-term action to address the major environmental and climate change issues; such mechanisms and strategies should include:

- improved dissemination of information about funding opportunities
- introduction of small-grant funding
- simplified application, administrative and reporting procedures
- provision of better support for operational and administrative costs
- introduction of long-term financing mechanisms
- broadened eligibility criteria to include traditional and indigenous forms of civil society organisation.

Recommendations to national agencies

1. Facilitate the implementation of EU policy and funding mechanisms in a manner that supports civil society involvement through effective communication, technical support and fair and transparent allocation procedures.
2. Improve, where appropriate, the transparency and effectiveness of public consultations in the ORs and OCTs through:

   more systematic processes for identifying and communicating with stakeholders

   more effective facilitation of civil society inputs, including those of individuals not associated with a formal organization

   more widespread dissemination of the findings of public consultations

   full consideration of the outcomes of the consultations.

3. Ensure that civil society organizations have access to the information they need to perform their role effectively, such as regular information about the processes and outcomes of international and intergovernmental meetings and agendas.

Recommendations to civil society organizations in the ORs and OCTs

1. Enhance technical capacity and strengthen advocacy through:

- development and enhancement of networks of civil society organizations at the local, regional, national and European levels
- development of strategic alliances and partnerships between:
- non-governmental organizations (NGOs) and research institutions
- civil society organizations and the private sector
- local civil society and international organizations
- continuously upgrading technical skills within civil society organizations to enable effective advocacy and partnership for implementation
- ensuring that systematic efforts are made to integrate and communicate with the full range of environmental stakeholders.

Recommendations to all actors

1. Design, provide funding for and implement projects aimed at drawing on and disseminating lessons and good practice related to the participation of civil society, at all levels.

E. Which strategies should be adopted for sustainable development research in the ORs and OCTs?

The overarching recommendation is to significantly increase the amount and scope of research conducted on biodiversity conservation, climate change adaptation and sustainable development in the ORs and OCTs. Further, more detailed recommendations include:

General

1. Develop a comprehensive approach towards the research challenges in the ORs and OCTs to ensure that activities implemented at the local and regional scales are consistent.
2. Promote the mobilization of civil society representatives by involving them in the development of research programmes.
3. Communicate research findings more effectively to policy-makers and civil society, not limiting these to publication in scientific journals; create appropriate funding mechanisms in support of this goal.
4. Translate the research results into policy, particularly in relation to spatial planning and economic development.
5. Ensure that supra-regional policies (States, EU, international conventions) reflect the needs of local populations and do not have negative consequences on local ecosystems.
6. Optimize research conducted in the ORs and OCTs by fostering synergies and complementarities, in order to overcome the disadvantages arising from their isolation, fragmentation and often small size.
7. Ensure that public policies generate the research means and resources necessary to fight and adapt to the impact of global environmental change in the ORs and OCTs.

Institutional, financial and toolbox needs

1. Establish long-term monitoring programmes as well as biological and socio-economic indicators adapted to the constraints specific to the ORs and OCTs, to measure, model and predict the impact of global change on ecosystems and socio-economic development. Make this data widely accessible and usable (compatible databases and collaborative internet portals).
2. Organize coordinated research into the impact of climate change on biodiversity in the ORs and OCTs.
3. Promote and fund dialogue and collaboration between OR and OCT research programmes (e.g. NetBiome) and similar initiatives designed to establish research priorities at the international and regional level (e.g. SIDS University Consortium).
4. Secure accommodation facilities and administrative support (harmonized legislative frameworks to facilitate work permits, visas where necessary, etc.) to facilitate exchanges between researchers, in particular between the ORs and OCTs, and between these and European countries.
5. Develop common protocols for conducting research and communicating research findings to the territories and communities studied
6. Develop the human resources required for research programmes and the fight against and adaptation to climate change.
7. Improve cooperation and exchange with all relevant stakeholders active in the field (local populations, naturalists, NGOs, students, protected area managers, etc.).
8. Incorporate ORs and OCTs more effectively into EU framework programmes and ensure that EU funding streams can be effectively accessed to implement priority research in the ORs and OCTs (determine regional contact points for ORs and OCTs, representation in programme committees, specific funds, etc.).

Specific research needs

1. Undertake in-depth studies into the impacts of global change on the biodiversity and local development of each OR and OCT.
2. Urgently undertake research and conservation actions on the most vulnerable ecosystems (insular mountains, coasts and reefs, Arctic and sub Antarctic).
3. Develop common methodologies for monitoring climate change and biodiversity in ORs and OCTs.
4. Conduct interdisciplinary research into the role of biodiversity as an indicator of and adaptation factor to global change.
5. Conduct research to develop tools and methods for biodiversity conservation and management.
6. Conduct long-term multidisciplinary research into the interactions between human societies, natural ecosystems and exploited lands exposed to climate change.
7. Develop a large-scale research programme mobilizing all the stakeholders concerned by ORs and OCTs, taking into account the characteristics of the different territories, to propose global answers to environmental change.

F. Which partnership between ORs, OCTs, Member States and the European Commission should be adopted to promote the protection of habitats and species?

Recommendations for the creation of a voluntary scheme for the conservation of habitats and species

1. The first approach should look at a higher bio-geographical level, subsequently to be adapted to local conditions.
2. The scheme should allow for contract tools as well as for regulatory approaches; existing tools should be utilized (e.g. IUCN or CBD approaches).
3. Natura 2000 should be used for inspiration, but not necessarily viewed as a model for direct application.
4. The scheme should be based on selecting sites of particular interest rather than specific protected areas (but those already existing may be part of the scheme) and be based on scientific, and if appropriate, ethical criteria; criteria for selection of sites should take into account the high level of endemism as well as representativeness of habitats and species; site selection should use proven methodologies such as BirdLife's Important Bird Areas (IBA) or Conservation International's Key Biodiversity Areas.
5. The scheme should take into account relevance to islands and specifically small islands.
6. Any financial scheme should be easy to access (via knowledge-based information systems); accessible, clearly identified contact points in Brussels are needed.
7. Local authorities play a major role both in entering the scheme and in its local implementation; voluntary commitment by local authorities is key to success.
8. Civil society should participate in the scheme.
9. There is a need for capacity building.
10. The scheme should allow for broader regional collaboration (outside of ORs and OCTs).
11. It must take into account the lack of data; this should not prevent its implementation.
12. The scheme would benefit from the existence of a coordination body or mechanism.

Species Conservation

1. Coherent use of Red Lists at different scales is important to define priorities, and the regular updating of Red Lists is a key issue.
2. Funding is key to implementation.
3. Better use of existing studies and methods (IUCN and others) is vital.
4. IAS management is an important part of the strategy.
5. A special approach is needed for migratory species.
6. Along with defining protection plans, there is a strong need for environmental education accompanied by the necessary controls.
7. Species and their distribution can be used as indicators of climate change impacts and for identifying potential future refuges.
8. The species approach is also a way to reinforce cooperation between ORs and OCTs.
9. The EU and Member States should not only represent the ORs but also the OCTs in international fora for species protection (CITES, CMS, etc.).

Networking among existing national parks and other protected areas

1. All protected areas should be given an opportunity to join the network, not only national parks.
2. Special attention should be given to small islands.
3. The network must be sustainable (hence not too ambitious).
4. Capacity building for managers is a key issue (especially in small islands).
5. Networking should be thematically rather than geographically oriented.
6. Networking could be integrated in the voluntary scheme.
7. Networking could allow monitoring of climate change impacts on biodiversity.
8. More attention should be given to the development of a legal framework for National Parks, where appropriate.

G. How should an energy revolution be achieved in the ORs and OCTs?

Recommendations

1. Undertake assessments of the environmental, social and economic impacts of all proposed OR and OCT energy strategies. Global warming is an element that should be considered. Other issues include the development of energy solutions appropriate to the population and income level of ORs and OCTs, access to electricity (development of island grids), securing the needs of the population, job creation and environmental costs.
2. Involve local electric companies or relevant energy providers in an ambitious policy of developing renewable energies with zero greenhouse gas emissions (e.g. covering, where technically feasible, 50% of electricity needs by clean energy by 2020) and no negative overall impact on biodiversity, while simultaneously addressing electricity consumption (including domestic, business, and tourism usage) in order to achieve energy efficiency.
3. Adapt local regulations and urban planning projects to take account of energy challenges: for example, thermal regulation in buildings to afford better energy-efficiency by using measures such as solar water heating, wall-insulation, loft-lagging and triple glazing. Establish eco-neighbourhoods and/or industrial eco-zones that use integrated approaches that take into account the energy dimension together with land transport needs.
4. Put in place long-term financial schemes involving governments and local financial institutions (development agencies), as well as European financial institutions (European Investment Bank) with soft loans adapted to needs, and investment funds for reinforcing locally sourced funds (private equity). Regarding the populations, subsidies or fiscal mechanisms can assist in sharing good practice. There will be large impacts on the building sector (both new and restored) and transport sector (promotion of sustainable public transport). Lowering the costs of energy-efficient solutions will require economies of scale.
5. Select an institutional framework capable of responding to the challenges posed by climate change and energy consumption using working groups mobilized with a longer-term perspective as well as for action in the medium term (2010 – 2015), giving priority to the transfer of best practices and technologies; specialized agencies (“energy efficiency units”) dedicated to the implementation of actions in the field of energy efficiency and the management of energy consumption must be established within ministries or electricity suppliers. Connecting these agencies may provide a solution in the search for maximum effectiveness (sharing of experience).
6. Facilitate networking in island regions (e.g. cooperation programmes in the Indian Ocean) to share best practices and conduct joint activities (e.g. training of senior management, research facilities). Energy observatories also offer possibilities for collaboration (development of tools, monitoring of action plans).

H. How should overseas marine environmental challenges be integrated into EU policies?

Recommendations

1. Define a long-term strategic vision that integrates bio-geographic aspects, via key EU funding mechanisms and policies such as the OR Strategy, the OCT Association clause and the EU Maritime Policy, that reflects the great importance of the maritime areas in the ORs and OCTs and the ecosystem services they provide.
2. Establish and financially support an eco-regional approach to prioritize conservation actions (research and management) in the ORs and OCTs that will actively engage local communities, fishermen, and NGOs (e.g. by reinforcing the POSEI Fisheries Programme with another on Marine Biodiversity).
3. Design a specific instrument or tool to build, manage and protect a representative network of key coastal and marine sites in the ORs and OCTs, complementing the existing Marine Directive. Support the conservation work of local NGOs.
4. Fully incorporate Integrated Coastal Zone Management as a fundamental aspect of regional policy in island entities.
5. Establish a specific programme on the integrated management of coastal zones and marine areas for the ORs and OCTs, by creating a joint forum to share best practices, develop tools and pilot projects on integrated planning.
6. Increase resilience of marine ecosystems by addressing anthropogenic stresses that will reduce pollution, organic matter input, and extraction to limit effects of climate change.
7. Reach out more strongly to the wider public, in order to raise awareness about the importance of the ORs' and OCTs' marine areas. Communicate the values and challenges inherent to the conservation of overseas territories and small island states. Raise awareness through education, training, and by working with NGOs.
8. Reinforce regional cooperation through development and regional policies.
9. Promote the establishment of a governance mechanism that enhances the involvement of local civil society and the private sector; establish regional mechanisms for dialogue among different sectors and stakeholder groups to enhance the coherence of maritime and coastal development (e.g. tourism, aquaculture, shipping, fisheries, energy, etc.).
10. Ensure appropriate consideration in the Red Lists of emblematic marine species in the ORs and OCTs, recognizing that migratory marine species in particular are also present in other jurisdictions and will require the EU to work in a broader context.
11. Enhance coordination and coherence of the different EU budget lines at the political level, with clear definitions of objectives.
12. In view of the proliferation of different certification and eco-labelling schemes, foster greater intra-regional and inter-regional cooperation in order to negotiate and adopt a common approach.

EU Common Fisheries Policy, and the sustainable management of fisheries resources

1. Conduct stock assessments, as a key element in sustainable fisheries, focusing on deep sea species as well as on migratory, exotic, demersal and pelagic species. Research and data collection should be coordinated at the regional level.
2. Adopt a bio-geographic approach to fisheries resources management.
3. Undertake environmental impact assessment for all new fisheries and aquaculture operations.
4. Increase participation of ORs and OCTs in the EU decision-making processes on fisheries.
5. Strengthen capacity building in the ORs and OCTs for enhanced negotiation and participation in the RFMOs (Regional Fisheries Management Organizations) and similar mechanisms.
6. Raise awareness of civil society of the challenges of fisheries management.
7. Consider the creation of one central or several Regional Advisory Councils (RACs) for ORs, and explore options to integrate representation from and/or issues of relevance to the OCTs.
8. Reinforce or establish a multilateral approach for control of illegal, unregulated and unreported (IUU) fisheries and regional cooperation for surveillance and control; consider extending the very effective EU-funded programme for control of fishing activities in the Indian Ocean to other regions.
9. Extend the recently adopted EU ban on landings of illegally caught fisheries products to those ORs and OCTs where it does not yet apply.
10. Establish political and financial support for local small-scale fisheries.

I. How should regional cooperation in ecological challenges be strengthened?

Recommendations

1. The EU and its Member States should facilitate networking and collaboration by:

- promoting or creating appropriate legal frameworks that allow for the participation of ORs and OCTs in regional programmes
- providing opportunities for exchange of information and experience on a regular basis, including low-cost communication systems
- working with and strengthening existing institutions and processes within regions.

2. The EU and its Member States should ensure that their tools and competencies (centres of excellence, financial mechanisms and others) are made available to their partners within regions by communicating more effectively.
3. Processes of regional cooperation should use and build existing expertise and facilitate the exchange of experiences, skills and resources.
4. Regional cooperation should be based on the formulation of regional priorities, and actors should communicate these to potential sources of support.
5. Research and academic institutions, civil society organizations and the private sector should play a full role in regional cooperation by building and promoting partnership.
6. All actors should take advantage of the opportunities offered by global institutions and initiatives, such as GLISPA and IUCN, that have demonstrated their capacity to create new synergies and linkages.

J. Which sustainable financial mechanisms can help address the ecological challenges facing the EU's ORs and OCTs?

Request the EU to work closely with Member States as well as with OR and OCT stakeholders to achieve the following:

1. Establishment of a dedicated fund for biodiversity conservation to offer additional financial support for conservation measures, field surveys and monitoring of biodiversity, as well as for research on the economics of ecosystem services for public benefit in order to persuade decision-makers of its importance.
2. Review of existing funding streams available for the ORs and the OCTs and their allocation criteria, with the aim of increasing their environmental sustainability.
3. Environmental and social impact assessments of all development projects and programmes at the identification and evaluation stages (condition of funding) so that they take full account of environmental and social considerations, and incorporate mitigation and compensation schemes where necessary.
4. Establishment of financial instruments for small projects; the selection process of the projects eligible for funding should be delegated to the local decision-making level.
5. Raised awareness of the economic value of biodiversity and ecosystem services to different levels of civil society and governments.
6. Strengthened effectiveness of public consultation by improving local processes.
7. Creation of a support unit in the ORs and OCTs for the preparation of project and programme proposals for submission to funding organizations.
8. Creation of trust funds to ensure protected area management and further conservation measures over the long term.

K. Moving towards a working platform on ecological challenges in ORs and OCTs

In the face of climate change and biodiversity loss in ORs and OCTs, the participants recognize the urgent need for a flexible and open network, aiming in particular at the following:

1. Contributing to increasing awareness among all stakeholders about the unique challenges faced by ORs and OCTs.
2. Supporting and strengthening relations, exchanges and initiatives between stakeholders including politicians, scientists, businesses, civil society, and the numerous and valuable networks already existing at the local, regional, national and European levels.
3. Identifying key challenges and establishing thematic initiatives at the scale of all ORs and OCTs, taking into account those which already exist at the local, regional, national and European levels.
4. Facilitating dialogue between all concerned stakeholders in order to build consensus on policies to be developed at the European level and securing their funding.
5. Following-up on the implementation of the Message from Reunion Island and organizing future work in collaboration with all concerned stakeholders; possibly organizing a new event/conference.
6. As several successful platforms already exist, a light value-added coordination mechanism must be identified that optimizes overall effectiveness.

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