SCIENCE FOR A BETTER LIFE:
DEVELOPING REGIONAL SCIENTIFIC PROGRAMS IN PRIORITY AREAS
FOR LATIN AMERICA AND THE CARIBBEAN

VOLUME 1

BIODIVERSITY IN LATIN AMERICA AND THE CARIBBEAN: AN ASSESSMENT OF KNOWLEDGE, RESEARCH SCOPE, AND PRIORITY AREAS

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ICSU
International Council for Science
Regional Office for
Latin America and the Caribbean

CONACYT
Consejo Nacional de Ciencia y Tecnología

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FOREWORD

Founded in 1931, the International Council for Science (ICSU) is a non-governmental organization that plans and coordinates interdisciplinary research to address major issues of relevance to both science and society. Over the years the geographical breadth of ICSU activities has changed. Increasingly a major emphasis for ICSU has been the development of scientific capacity in developing countries and the integration of these scientists in international research initiatives.

The creation of three ICSU Regional Offices, established in Africa, Asia and the Pacific, and Latin America and the Caribbean also marks a fundamental change in ICSU structure, the aim of which is two-fold. First, it should enhance the participation of scientists and regional organizations from developing countries in the programs and activities of the ICSU community. Secondly, it will allow ICSU to play a more active role in strengthening science within the context of regional priorities through scientific collaboration.

Especially in regard to Latin America and the Caribbean, this is an important step in bridging the 'islands of competence' that exist in every country and that together will be able ato advance significantly the scientific research agenda in the region. The first step towards the establishment of a Regional Office was the appointment in 2006 of the Regional Committee for Latin America and the Caribbean, composed of renowned scientists of the region.

The Regional Office for Latin America and the Caribbean was the third to be established and was inaugurated in April 2007. It is hosted by the Brazilian Academy of Sciences, in Rio de Janeiro, Brazil, and supported by the Brazilian Ministry of Science and Technology, ICSU, and CONACYT Mexico. From October 2010 it will be hosted by the Mexican Academy of Science, with the support of CONACYT Mexico.

Based on the ICSU Strategic Plan 2006-2011, the Regional Committee has selected four priority areas to be developed:

- Mathematics Education;
- Biodiversity: knowledge, preservation and utilization of biodiversity of all countries of the Latin American and Caribbean region, and to ensure that the scientific community of the smaller countries of the region are fully integrated in DIVERSITAS;
- Natural Hazards and Disasters: prevention and mitigation of risks especially of hydrometeorologic origin with special attention to the necessary social science research;
- Sustainable Energy: assessment of the existing capacities in the LAC region and the social impact of the use and development of new energy resources.

Four Scientific Planning Groups were appointed to develop proposals that reviewed the current status of the priority area in the region and to formulate a set of detailed objectives and targeted areas of research to be developed in the next few years.

Engaging highly qualified scientists from Latin America and the Caribbean, the Scientific Planning Groups did outstanding work within a restricted time limit. We thank each and every one of the participants for their enthusiasm and dedication.

This document is the final report of the Scientific Planning Group in Biodiversity, which is being submitted to the scientific community in the expectation of effectively influencing the development of scientific research in this area in the years to come.

Alice Abreu
Director
Regional Office
for Latin America and the Caribbean

José Antonio de la Peña
Chair
Regional Committee
for Latin America and the Caribbean

EXECUTIVE SUMMARY

Biodiversity, world's natural capital, is the result of millions of years of organic evolution tailored by the hand of the environment. It comprises the living component of the Life Supporting System of our planet and is the source of numerous and vital ecosystem services. The loss of biodiversity constitutes a critical problem for human existence to the extent that biodiversity science is amply recognized as a priority area of scientific research in both the developed and developing world.

Biodiversity science spans a wide range of basic scientific disciplines ranging from molecular genetics through to systematics, population through to ecosystem ecology and macroecology, as well as integrative research areas such as conservation biology, biocultural conservation, impacts of climate change, complex systems, ecological economics and environmental ethics.

The aims of this document are to: a] provide a snap-shot assessment of the state of knowledge of biodiversity in Latin America and the Caribbean (LAC), so as to situate the region's biodiversity on the global stage; b] critically assess biodiversity research undertaken in the region so as to identify knowledge gaps and needs; c] assess institutional capacity for biodiversity science in the region and identify the main biodiversity research centers; and, d] arrive at a set of priority research themes and identify capacity, infrastructure and other needs for implementing the ICSU-LAC biodiversity science plan.

For the purposes of this study, LAC is understood as all nations and dependencies in or immediately off the coasts of Mexico, Central and South America, as well as those in the Caribbean Sea.

The first section of the assessment is devoted to setting the context under which LAC´s biodiversity developed. Palaeogeographic evolution of the region over more that 100 Ma precipitated increasing compartmentalization of the LAC region resulting in a marked increase in biome and habitat diversity throughout the Cretaceous, Tertiary and Quaternary, while the arrival of humans as of 14 500 BP, was paralleled by intensive cultural diversification and mostly non-intensive land use. Up until pre-Columbian times, the physiographic evolution of the region together with the outstanding cultural diversification of the Amerindians, reflected in hundreds of languages, generally favored the accumulation of biodiversity and related cultural knowledge. A reverse trend was set into motion in post-Columbian time, culminating in today's large-scale agriculture, plantation forestry and increasing urbanization. The projected urban population in the year 2050 exceeds the entire population of LAC today, with loss of traditional knowledge to be expected.

The assessment's second section shows that LAC monopolizes the Planet's biodiversity through a detailed overview of: diversity of biogeographical divisions, diversity of ecosystems, diversity of species, diversity of life forms and functional groups, concentration of endemic organisms, agro-biodiversity associated with cultural diversity, Biodiversity Hotspots and Frontier Forests, and diversity of biotic interactions. Some highlights are: six countries of LAC fall into the Megadiverse league; 32% of global biodiversity in vascular plants, summing to an estimated 95 000, for a land area constituting 9.6% of total land area worldwide; in South America: 33% of global biodiversity in birds, 32% of anurans, 25% of mammals and 20% of reptiles; two Vavilovian Centers of Origin of Agriculture and Plant Domestication; seven of the 25 Biodiversity Hotspots for Conservation Priority; a recently-discovered Hotspot for bryophytes at the extreme southern end of South America; 22% of global Frontier Forest. Brazil, the largest country in LAC, has an estimated 170-210 thousand described species considering all taxonomic groups, but is believed to have around 1.8 million in total, taking into account microorganisms and fungi.

Knowledge emerging from molecular phylogenetics, genome sequencing, the study of the ecosystem services of biodiversity, and the exploration of unusual biodiversity and habitats, is also reviewed, where the South American Andes have recently revealed some of the highest speciation rates in the world. It is concluded that major knowledge lacunae are still evident in many groups of organisms/countries, yet there are outstanding regional efforts, such as the Catalogue of the Vascular Flora of the Southern Cone project, amalgamating knowledge on the floras of Argentina, Chile and southern Brazil. Huge asymmetries with respect to basic knowledge and/or its accessibility characterize marine and freshwater versus terrestrial habitats.

A serious problem in general concerns the lack of geoferenced biodiversity data and the willingness of institutions, with some notable exceptions (e.g. CONABIO, INBio), to make data available on online.

The study of ecosystem services is hindered by the lack of data on carbon sequestration, nevertheless, economic valuations of some ecosystem services are beginning to appear, and ecotourism and its variants are well developed in the region.

In the same section, we consider the main threats to biodiversity and the state of research insofar as detecting impacts of such threats. Main threats are deforestation, fire, over-exploitation, the introduction of exotic species, climate change, and pollution. It is particular worrying that: South America suffered the greatest ever-net forest reduction over the years 2000 to 2005; the Brazilian Cerrado is now disappearing at more than twice the rate as the Amazon rainforest, and; rates of deforestation in Megadiverse countries like Mexico are still very high. LAC´s terrestrial, fresh-water and marine habitat have already received large numbers of exotic species, spanning the taxonomic hierarchy, but our knowledge regarding specific impacts on biodiversity is woefully incomplete. With globalization and greater regional integration, each country can be expected to receive additional invaders.

Climate warming in LAC should lead to easier pole ward migration of species in the northern extreme than in the southern part of LAC, as a result of the fact that the amount of land increases with an increase in latitude north of the tropics, while in the South America south of the equator, the opposite is true. Results of the first modeling studies on the impacts of climate change suggest certain losses of biodiversity, along with complex feedbacks between drivers such as deforestation and climate change, leading to an exacerbation of global warming. However, experimental studies on the impacts of global warming are still few. The steep altitudinal gradients in the Andes, replicated over many degrees of latitude, provide an, as yet, largely untapped model for assessing the impact of climate change on biodiversity. Climate change research at an ecosystem level is hindered by the lack of long-term data sets and the compilation of regional data sets, although there are some notable exceptions.

As a result of increasing human affluence, coupled with climate warming, Antarctica is considered to be extremely vulnerable to biological invasion. The impacts of pollution in LAC´s marine ecosystems are likely to be extensive, judging on the results of the little research on this driver of biodiversity change.

The penultimate part of the assessment then goes on to critically examine the conservation of biodiversity and what the research effort in LAC has achieved and reveals. Close to 8 500 plants and animals in LAC are considered to have conservation problems by IUCN standards, but this number is concluded to grossly underestimate the real situation. The most threatened groups are amphibians (32% of total) and fishes (24%); however, the vast majority of species catalogued as endangered (67%), are plants.

Although 21% of LAC´s land area is protected –the highest percentage contribution for all developing regions of the world, and higher than in the developed countries– distribution modeling and GAP analysis reveals that the present configuration of protected areas is not always optimally located to protect the region's biodiversity. Moreover there are huge imbalances comparing the protection of wet forest versus dry forest and scrubland habitats, represented in the last case by the central Chile and the Brazilian Cerrado, two Global Biodiversity Hotspots for Conservation Priority, both with minimal protection. The situation calls for a more balanced conservation effort across the region. It is concluded, moreover, that more focus on the agroscape and other variants of the managed matrix is called for. Where there are no land owners, as in the sea and coastal waters, and especially along the colder and less charismatic coasts of LAC, the development of Management and Exploitation Areas for Benthic Resources, has met with some success in quelling biodiversity loss.

The last part of the assessment presents an overview of institutional arrangements and resources for biodiversity research. The latter shows that LAC has many institutions devoted, at least in part, to biodiversity science, among which are found several novel institutions of international standard fully devoted to biodiversity research. However, overall, biodiversity scientists in LAC, particularly ecologists, have been slow to rise to the challenge of tackling large-scale, complex problems through networking and data sharing.

It is evident that the vast and biologically-rich LAC region with its present man power and institutions presents an outstanding opportunity to develop biodiversity science in many different dimensions. In developing the section on research priorities emphasis was given to promoting integrative international-level science of relevance to society, while opening a window of opportunity so as to keep abreast of present global trends in biodiversity research and to prepare scientists and students to work in a collaborative and networking mode. The biodiversity science plan also aims at correcting knowledge asymmetries, as those between terrestrial versus fresh water and marine habitats, and important geographical gaps in knowledge, such as the lack of a published checklist for the flora of Brazil. Scientific advances and reorientation of the scientific effort are deemed necessary to adequately answer relevant questions in a time of climate change and inadequate land use change.

The priority research themes recommended by the SPG on Biodiversity are:

- Development of georeferenced data bases and completion of biological inventories for testing hypotheses on the large-scale planetary patterns of biodiversity and for detecting the impacts of global change drivers, climate change included, on biodiversity, with emphasis on the major knowledge gaps, as well as on the opportunities provided by LAC´s model ecological gradients.
- Synthesis of molecular phylogenetic information for the region with the aim of detecting phylogenetic patterns and phylogenetic diversity in the biota of Latin America and Caribbean.
- Evaluation of the biodiversity and ecosystem services on managed and unmanaged landscapes and of the conservation status of organisms that play known important ecological roles, including biological control agents and pollinators.
- Consolidation of a network of Ecological Observatories in LAC to undertake experimental studies and long-term monitoring on the impact of climate and land use changes on biodiversity.
- Development of a regional-scale assessment of the impacts of invasive species in the context of early warning systems.
- Transference of biodiversity and biocultural knowledge into sustainable economic activities, including any benefits of bioprospection, and the conservation of critical ecosystem services.
- Finding solutions for the implementation of biodiversity conservation measures in managed landscapes and seascapes.
- Development of studies on the ecosystem service value of urban biodiversity.

The biodiversity science plan envisages new modeling and experimental research, as well as the synthesis and analysis of available information. The research priorities are consistent with the DIVERSITAS Science Plan and the eventual implementation of IMOSEB or some modification thereof. Several priorities interface directly with recommendations of the Millennium Ecosystem Assessment. Links to numerous biodiversity initiatives and thematic networks, such as GEOSS, GMBA, and ILTER are evident. It is recommended that all researchers and graduate students participating in research financed by the ICSU-LAC Biodiversity Research Program be required to undertake outreach activities outside the academic domain.

Capacity building needs to include: training and integrating taxonomists into various areas of the science plan; training LAC´s scientists on the value of collaborative research, integrative approaches and international networking; training specialized personnel and young researchers in the areas of informatics and data management; preparing scientists to interact with the press and engage in outreach.

The incorporation of postdoctoral researchers and research internships is considered fundamental for the success of the program and for further internationalization of the participant institutions. Costly state-of-the-art automated equipment for registering environment variables at field sites, enhanced computer power, availability of satellite imagery and imaging capacity are the main infrastructure needs.

Finally, a number of ideas on how the biodiversity science plan might be financed are offered. Evidently, the long-term ecological research requires a strong commitment from governments or regional bodies such as OAS to provide costly field equipment for monitoring climatic and other variables, and for the maintenance of such equipment. The cost of implementing the biodiversity science science plan is estimated at an average of US$3 million per year.

SCIENTIFIC PLANNING GROUP AND REGIONAL COMMITTEE

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This report turned out to be larger than was originally planned. We sincerely hope the length of the document is a sign of the worthiness of supporting biodiversity research in Latin America and the Caribbean and indicative of the amount of

funding that will be forthcoming to make the ICSU-LAC Science Plan a reality. If the document only goes as far as reinforcing the message of the extraordinary natural capital of and the formidable threats to Latin America and the Caribbean among our colleagues, students and the general public, the time spent will have been well worthwhile.

1. INTRODUCTION

1.1 BIODIVERSITY AND BIODIVERSITY SCIENCE

Biodiversity, the result of millions of years of organic evolution tailored by the hand of the environment, comprises the living component of the Life Supporting System of our planet, and the source of numerous and vital ecosystem services to humanity-our planet's natural capital. Biodiversity not only contributes directly to the functioning of natural ecosystems, but also, when transported inappropriately around the globe, can lead to serious ecosystem disruptions. At the same time, abrupt environmental change, such as climate change and inadequate land use, can lead to ecosystem reordering and/or the loss of biodiversity along with altered ecosystem functioning, in turn, potentially affecting the delivery of key ecosystem services such as carbon sequestering, and the integrity of the very substrate that underpins the sustainable livelihood of millions of people worldwide. The loss of biodiversity thus constitutes a critical problem for human existence at several different levels, to the extent that biodiversity science is now amply recognized as a priority area of scientific research in both the developed and developing world (Loreau et al., 2006).

Biodiversity is defined as the variety of life on Earth at all its levels from genes to ecosystems. Genetic diversity, expressed at the level of the gene through mutation and other processes, has been aptly termed the "fundamental currency of diversity" and is ultimately responsible for variation between individuals, populations, species and higher taxonomic entities. Populations and species are the basic evolutionary units that interact with one another in ecological time and space to produce such characteristic manifestations of biodiversity as species richness and the functional diversity of an area. Species in turn, are assembled into ecosystems, the structure and functioning of which are determined by the intrinsic properties of, and interactions between species, molded in turn, by the abiotic environment. Reflecting the latter and the functions of biodiversity, modern biodiversity science includes the discovery of biodiversity, the evolutionary and ecological processes that produce, sustain and are responsible for the distribution of biodiversity on Earth, together with the analysis of ecosystem services and socio-economic values provided by biodiversity and the search for means to conserve and use it in a sustainable way. If it is accepted that humans are part of nature, then cultural diversity, should also be considered as part of biodiversity. The conservation of biological and cultural diversity requires an interdisciplinary approach whereby social and ecological dimensions become linked as part of a common whole.

Because biodiversity is a broad and all encompassing notion, biodiversity science spans a wide range of basic scientific disciplines ranging from molecular genetics through to systematics (alpha to molecular), population through to ecosystem ecology and macroecology, as well as many integrative areas of research. The loss of biodiversity on Earth as a result of inadequate land use practices, and the emerging impacts of climate change on biodiversity, together with complex feedbacks between these last-mentioned drivers, places scientific research in the areas of conservation biology, biocultural conservation, impacts of climate change, complex systems, ecological economics and environmental ethics, at the center of biodiversity science as we enter the twenty-first century.

Latin America and the Caribbean (hereafter LAC), the subject of this report, is a geopolitically and culturally diverse area of the world. Such political and cultural diversity, when added to LAC´s biological diversity, should be seen as an opportunity more than an impediment to developing biodiversity science of relevance to human society. Adequately harnessed, and with appropriate financial support, it could be central to developing a novel approach to biodiversity research and conservation.

1.2. AIMS OF THE REPORT

The primary aim of this document, requested by ICSU-LAC, is to arrive at a Science Plan along with capacity building and infrastructure needs for biodiversity research in LAC region in the context of international-level science. Given the enormous growth in scope of biodiversity science over the past 10 years, it should be more than evident that this is not an easy task. In order to develop the research priorities, therefore, we have considered it essential to *provide an assessment of the state of knowledge of biodiversity in the region, looking at the different facets that pertain to biodiversity research and where Latin American scientists are making contributions. The assessment will also provide brief descriptions of three quite different research institutions that are devoted to biodiversity science in the region, together with two examples of ongoing integrative research efforts.* The assessment presented here, in no way claims to be exhaustive, neither in breadth, nor in terms of the examples and literature cited. Nor do we provide any quantification of the number of scientists involved in biodiversity research. Any imbalances can be put down to limitations imposed by the backgrounds and knowledge of its five authors and the complexities associated with covering such a broad area of scientific enquiry and large geographical area in a short period of time.

1.2.1. Structure of the assessment

The first section of the assessment is devoted to setting out *the context* under which LAC´s biodiversity has developed, placing emphasis on: a] the palaeogeographic and climatic evolution of the region as large scale drivers of biodiversity and its present-day distribution; b] early human occupation and the emergence of coupled human-environment systems; c] trends in land use and in population growth as of post-Columbian times. The main message we will leave here is that up until PreColumbian times, the physical evolution of the region and early human occupation generally *favored the accumulation of agrobiodiversity and related cultural knowledge*, and that there are many lessons to be learned of relevance to a biodiversity research strategy.

The second section of the assessment is devoted to demonstrating that *LAC is the most biodiverse region on the planet* through detailed consideration of a series of biodiversity metrics and approaches. Here we point to knowledge lacunae in many groups of organisms and in certain countries, and highlight the asymmetry of knowledge and/or its accessibility in marine and freshwater versus terrestrial habitats.

The third section of the assessment considers the *main threats to biodiversity* and the state of research insofar as detecting the impacts on biodiversity and contributing to their mitigation. This section concludes that research in this critical area for the region lags behind and must be increased in scope so as to make it more relevant to society and on the international scenario.

The fourth section of the assessment critically examines where we are in LAC insofar as the *conservation of biodiversity* is concerned and what the available research results suggest should be done. In this section, the main conclusion is that present protected areas in the region are inadequate for protecting biodiversity, trained manpower is limited for this kind of research, and that other kinds of protective measures will be necessary.

The assessment has been written in such a way as to detect specific research needs as we go along in relation to key research questions and the present knowledge base. In the fifth section of document, we draw the many of specific research needs together to organize them into a set of research priorities.

While the final science plan stresses the need for integrative international research of benefit to human society, it also recognizes that for the outstandingly biodiverse LAC region to make a real contribution both intellectually, and in terms of biodiversity conservation, such research is necessarily highly dependent on the quality and geographic representation of knowledge generated in the more basic disciplines of biodiversity science, such as taxonomy and ecology. At the same time, it acknowledges that large scale regional and international efforts in biodiversity research today rely heavily on informatics and information stored in large georeferenced data bases, and in the near future will increasingly use genomic techniques, while regional and global comparative ecological work in the biodiversity domain requires experimental approaches and comparative long-term studies, all of which signify a commitment to costly and long-term investments.

The section on capacity building, in addition to promoting basic research training per se, stresses the need for the region to produce a new generation of scientists who are adequately equipped to integrate collaborative research efforts at the regional and global levels.

1.2.2. Definition of the Latin American and Caribbean region

Living organisms (other than the human species) do not recognize political boundaries. Thus throughout this document we adhere to a biogeographical definition of LAC. LAC will be understood as all nations and dependencies in or immediately off the coasts of Mexico, Central America and South America, as well as those in the Caribbean Sea. Mexico and Central America contain eight independent countries while South America is comprised of twelve nations as well as French Guiana (part of France). The Caribbean is comprised of 13 separate island nations and 11 islands or island groups, these last variously belonging to Britain, France, The Netherlands and the USA. Included also are the Falkland/Malvinas Islands and Galapagos Islands off the coast of South America. Two countries of LAC have official claims to territory on Antarctica (Chile, Argentina), while one, Brazil has an unofficial claim.

2. THE ASSESSMENT

2.1. LAC - AN ECOLOGICAL THEATER FOR BIODIVERSITY

2.1.1. The physiographic context

With 20.6 million km^2, representing 9.6% of the world's total land area, and surrounded by extensive oceans signifying total marine territories in the Exclusive Economic Zone of 20-28 million km^2 and marine Territorial Seas of approximately 1.5-2 million km^2, the argument can be made *a priori* that LAC is a globally relevant theatre for biodiversity. Straddling both sides of the tropics, extending to the doorstep of Antarctica, and characterized by steep altitudinal gradients compressing temperature conditions found over many degrees of latitude into compact altitudinal zones, on land, LAC supports subpolar, temperate, subtropical and tropical ecosystems. Included is the largest extension of tropical forest and one of the world´s principal areas of carbon storage, tropical to temperate alpine biomes, the southernmost piece of temperate forest in the southern hemisphere and the northernmost point of the distribution of tropical rain forest. There are several recognized Biodiversity Hotspots for Conservation Priority and some of the most important centers of origin of agriculture and plant domestication. In the sea, one of the most productive marine areas in the world is found in LAC.

LAC extends from latitude 32°43´ North latitude to almost 56° South latitude. The Andean mountains, running continuously along the western flank of South America for 45 degrees of latitude, house all southern hemisphere peaks over 4 000 m. a.s.l., and all the world´s 54 volcanoes over 6 000 m.a.s.l, these last associated with unique thermal, and the expected habitats, of unusual microorganisms. LAC´s tectonic legacy and geomorphology have endowed it, not only with the Andes and the tectonically equivalent lower mountain ranges running through Mexico and Central America, but also with 0.36 million km^2 of inland water bodies, including five of the 20 longest rivers in the world (Amazon, Paraná, Purus, Madeira, San Francisco). LAC is the home of three of the world's eleven largest wetlands (Pantanal, Amazon wetlands, southern South American temperate peatlands; Junk et al., 2005; Alho, 2005, Arroyo et al., 2005). To these inland water bodies must be added a plethora of islands in the Caribbean and ca. 1 300 km of fiords in southern Chile, contributing to the close to 64 000 km of coastal marine habitats, the equivalent to 17.9% of the world total, and the presence of a nearly "inland" sea, the Sea of Cortés, off the Baja California Peninsula.

With respect to marine habitats, LAC is surrounded by three large oceans, the Antarctic in the extreme south of the region, the Pacific and the Atlantic, covering 8 Large Marine Ecosystems. These oceans also include the Abyssal and Hadal underwater systems and Trench Floor environments that extend to >10 000 m. depth, where unusual biodiversity can be expected. The Central and Southeastern Pacific Oceanic realm is characterized by dynamic upwelling and non-upwelling systems such as the Humboldt Current System originating from the northward deflection of the Pacific West Wind Drift system on the western side of South America, and extending to central and Northern Peru. This current, bringing phytoplankton from Antarctica, determines one of the most productive marine upwelling systems in the world with fisheries representing up to 15-20% of annual total world landings. The Pacific Southern Cone of South America houses the shallowest Oxygen Minimum Zones (OMZs) in the world; when added to those of the Central Eastern Pacific, LAC accounts for approximately 65-75% of all OMZs globally. In addition, LAC houses the second largest coral reef zone on the planet, found off the coast of Mexico and Central America, and another very extensive reef in the Atlantic Ocean off the Brazilian coast (Amaral and Jablonski, 2005).

The physiographic diversity of LAC, not unexpectedly, is reflected in a wide variety of climates. Tropical conditions prevail over much of the terrestrial habitats in the region, given the larger amount of land found at those latitudes. However for the oceans, where the continental shelves are wider at temperate latitudes, both temperate and tropical conditions are well represented - a factor which will be seen to determine seemingly contrasting patterns of diversity on the land and in sea. The large-scale climatic determinants of LAC include relatively low pressures at the equatorial belt (10°N-10°S), quasi-permanent high-pressure cells over the north and south Atlantic and southeast Pacific Oceans, and a belt of low pressure defining the westerly flow over the southern portion of South America. Mexico, Central America and the Caribbean are affected by the penetration of cold fronts and tropical cyclones over the Atlantic and Pacific Oceans. A thermal low between 20-30°S east of the Andes determines a monsoonal circulation pattern, bringing seasonal precipitation to the Altiplano during the summer months and influencing the positioning of the Inter-Tropical Convergence Zone (ITCZ) in the region. On the western side of South America, the interplay of the ITCZ, the rain shadow effect of the Andes, the cold Humboldt Current and a weakened polar front determines the characteristic hyperaridity of the Atacama desert (Arroyo et al., 1988) and the so called "Arid Diagonal" traversing from the coast of Peru, across the Andes and down into Patagonia. On the other hand, at the southern end of the continent, climate is strongly affected by the westerlies and a dominant polar front, bringing much more precipitation to the western side of the Andes. The climate of the Atlantic Ocean and adjacent land areas is likewise strongly influenced by sea surface temperatures and winds. The primary circulation of surface winds over the Atlantic Ocean is characterized by a zonal distribution pattern oriented in an east-west direction. The greatest storm frequency, more than 30% in winter, is in the zone of the prevailing westerlies. Tropical cyclones (hurricanes) develop off the coast of Africa near Cape Verde and move westward into the Caribbean Sea. During the last 500 years more than 100 hurricanes have past over the Caribbean (Colón, 1977).

Additionally, LAC is affected by the decadal scale El Niño Southern Oscillation (ENSO). The sign and strength of ENSO-related climatic anomalies are geographically and seasonally dependent, rendering a complex picture of functioning in different parts of the region (cf. Garreaud and Aceituno, 2007) manifested in alternating cycles of drought and flooding.

This in a nutshell, is the complex environmental template over which the remarkable biodiversity of LAC has evolved.

2.1.2. Paleogeographic evolution

Biodiversity is the product of millions of years of organic evolution shaped by ecological processes and interactions with other living organisms, including, most recently, humans. The biodiversity of LAC has evolved and assembled under recurrent landscape and ocean transformation and continuous climate change throughout the last 100 million years. However, because South America has not deviated significantly in latitude since the Cretaceous, and tropical latitudes were less affected than their temperate counterparts by the Quaternary glaciations, the lowland tropics of South America, in a relative sense, have enjoyed greater long-term climatic stability, a factor that many authors over the years have argued, might contribute to the higher terrestrial biodiversity at tropical latitudes.

Terrestrial ecosystems

LAC´s tectonic history, in addition to influencing its geology and soils, has determined its overall proximity to other continents, and thus ease of biotic migration throughout the region and the possibility of expansion of clades between Mexico and Central America, the Caribbean, and South America. The general thrust has been for increasingly greater *ecological diversification of the LAC landscape over time*.

Geographically, the land area of LAC integrates the extreme southern portion of the North American plate (Yucatan peninsula northward, part of Cuba), the Caribbean plate (islands of the Caribbean, Central America, and some northern portions of Venezuela), small portions of the Cocos and Pacific plates (Baja California) and the entire South American plate, making LAC one of the most, if not the most, geologically complex region in the world. Up until around 118 Ma South America was connected to Africa, and until 30-40 Ma to Antarctica (Cook and Crisp, 2005; McLoughlin, 2001), resulting in indisputable legacies of these now distant geographical areas in LAC´s biota. South America and Central America remained unconnected until the formation of the Panamanian isthmus as of 15 Ma, with complete closure around 2.5 Ma (Marshall and Semper, 1993), at which time terrestrial interchange between North America, Mexico, Central America and

South America became expedite; coetaneously marine habitats in the Atlantic and Pacific became decoupled, indicating an interesting contrast for marine and terrestrial habitats.

On land, major inland seas were present in South America in the late Middle Miocene (Marshall and Lundberg, 1996), cutting off direct migration of plants and animals from east to west. Heightened uplift of the South American Andes in the Tertiary and Quaternary to over 6 000 m. a.s.l. as a result of subduction of the Nazca plate resulted in the so-called South American "arid diagonal" leading to strong east-west climatic differentiation and a significant geographical barrier to east-west migration, while at the same time a high altitude corridor came into being facilitating latitudinal migration of plants and animals for over 7 000 km. The development of the Sierra Madre Occidental at 34-15 Ma (Becerra, 2005) and uplifting of the central plateau in Mexico, as with the Andean uplift, had a significant effect on regional climate and drainage patterns. Likewise, the uplift of the Sierra Madre Oriental broke the continuity of Mexico's Atlantic coastal plains and promoted the development of significant rain shadows, thus favoring conditions for the establishment of deserts within the inter-tropical latitudes. A important side product of Andean mountain building and persistence of the moderately elevated ancient Guiana and Brazilian highlands was the formation of extensive drainage basins such as the Amazon (7 million km^2), the Orinoco (0.83 million km^2), the Magdalena (0.32 million km^2) and the Paraná (4 million km^2) in the Neogene, these characterized by younger and richer soils than the ancient Guiana and Brazilian continental shields and extended, easterly flowing rivers. Such basins today canalize 93% of the continent's freshwater drainage into the Atlantic and have contributed to the diversification of LACs ictiofauna (Lundberg et al., 1998). To the contrary, rivers flowing west of the Andes are mostly short and swift-flowing.

During the late Cretaceous and Paleogene, it appears that the land area of LAC was fairly low lying and covered mostly by wet tropical and subtropical forests (Graham, 1999; Ortiz-Jaureguizar and Cladera, 2006), including the far southern latitudes of South America. The latitudinal temperature gradients on the land and in the surrounding oceans would have been shallower than at present. Nevertheless, some authors sustain that the semi-arid and arid conditions in the Atacama date as far back as 150 Ma (Hartley et al., 2005). Worldwide climatic cooling in the Oligocene, and again in the Miocene-Pliocene reflected in the onset of glaciations in Antarctica, in conjunction with the heightened rain shadows produced by the Andes and the main mountain ranges in Mexico and Central America, led to latitudinal contraction of the tropical forest belt along with significant diversification of the major biomes in LAC to include extensive areas of tropical dry forests, mediterranean shrublands, cool temperate forests, grasslands, and semi-desert by the Miocene-Pliocene (Hinojosa and Villagrán, 1997; Ortiz-Jaureguizar and Cladera, 2006). Recent molecular work suggests that tropical dry forest in Mexico became prominent as of 30-20 Ma (Becerra, 2005). Many cool temperate forest elements migrated into Mexico and Central America from the north (Graham, 1999), and into the northern Andes from the southern temperate rainforest (Van der Hammen, 1974) in the Pliocene.

Needless to say, the isolation of South America from Central America and Africa during the Tertiary left a strong imprint on the biota of the Neotropics in general. As of the severing with Antarctica the Neotropical flora, fauna and microorganisms evolved in complete isolation. The emergence of a continuous land bridge to Central America, 2.5 Ma years ago, saw the arrival of temperate elements in the South American highlands and concurrent appearance of South American taxa in Central America, while there is strong evidence for the displacement of

Neotropical fauna, especially mammals, by northern immigrants. The mix of taxa in extant Mexican tropical floras derived from tropical South America, tropical Central America, and from remnants of northern tropical Eocene floras is a legacy of the impact that the establishment of the Panamanian isthmus had on the Neotropical region (Burnham and Graham, 1999).

The Pleistocene, a time of expansion of the Southern Patagonian ice caps, lowered eustatic levels, temperatures, and vegetations belts, affected both the temperate and tropical latitudes of LAC. Data on temperature changes during the late Tertiary and Quaternary point to low-latitude temperature fluctuations of up to 6 °C. Rainfall probably varied regionally, resulting in a mosaic of habitats controlled by river migration, sea level fluctuations, local dryness, and local uplift. At subtropical latitudes, significant changes in the distribution of summer and winter rainfall have been documented in northern Chile (Betancourt et al., 2000) and Mexico (Metcalfe et al., 2000).

During the Pliocene and Pleistocene glaciations, incredibly, South America lost 75% of its mammal fauna, with the extinction of no fewer than 51 genera (Meserve, 2007). One of the most interesting questions is to understand what this extinction event signifies evolutionarily and ecologically for the present day mammal fauna. Zones postulated as Pleistocene refugia provide testable hypotheses using neo-ecological and paleo-ecological data (Burnham and Graham, 1999). Although the Amazonian refugium hypothesis in its original guise tends to be questioned today, undoubtedly the effects of climate change on vegetation physiognomy played a crucial role in shaping not only the present patterns of mammalian distributions (Stebbins, 1981; de Vivo and Carmignotto, 2004), but also of present biomes and ecotones. The ranges of forest plant and animal species became fragmented and total forest cover was reduced during the LGM (Bonaccorso et al., 2006). At far southern latitudes in South America, temperate forests were mostly replaced by sub-antarctic tundra in the LGM.

Overall, the paleographic evolution of LAC, in conjunction with diversification of the regional climate, *precipitated an increasing degree of compartmentalization of the LAC terrestrial ecological theatre, resulting in a marked increase in biome diversity in the Tertiary, with a greater contribution of the more fire-prone biomes and temperate elements than in earlier Cretaceous times.*

Marine ecosystems

About 160-150 Ma, deltas and wetlands abounded along the coasts of land in the Caribbean Sea (Haczewski, 1976). Brought by marine currents that flowed from east to west, a great variety of plankton and invertebrates came to populate the Caribbean (Berggren and Hollister, 1974). With them, fish arrived and eventually an enormous diversity of carnivorous reptiles (Gasparini and Iturralde-Vinent, 2006). The K-T boundary event had a major impact in the Caribbean (Iturralde-Vinent, 2004) leading to restructuring of marine ecosystems as of the Paleocene, along with appearance of elements from the Atlantic and Pacific (Jackson et al., 1996; Prothero et al., 2003). With the closing of the Isthmus of Panama, Caribbean marine communities came to show greater similarity to those in the Atlantic with many new endemics appearing.

The Oligocene and the Neogene represent critical stages for the establishment of climatic and oceanographic conditions responsible for the present assemblages of species in the southeastern Pacific Basin. At around 32 Ma Drake Passage opened. Importantly, by about 12-13 Ma the Upwelling Coastal System of Peru was activated, followed by similar upwelling along the present Chilean coast at 5-6 Ma.

As a result, the actual Humboldt System came into being along the coasts of Chile and Peru.

During the Pliocene the connection between the Caribbean Basin and the Pacific was closed and the Panama Isthmus established. In the Pleistocene (*ca.* 2 Ma) the southern Chilean fiord systems developed. During the Holocene the modern Southern Oscillation (ENSO) came into force.

Paralleling the situation on land, in the Southeastern Pacific Basin coastal marine systems, the marine fauna was characteristically subtropical towards the early Miocene, while it became cold-temperate in Peru during the mid Miocene and also cold-temperate along the Chilean marine realm towards the late Pliocene. Massive marine faunal extinctions are recorded at the end of Pliocene such that the modern marine fauna only became established in the Southeastern Pacific during the Pleistocene. These massive faunal extinctions are particularly well documented among mollusks and especially bivalves.

The last 200 Ma of tectonic history of the LAC region, in additional to defining distinct biogeographic provinces, resulted in a huge diversity of continental platforms and coastal types, together signifying an outstanding diversity of marine habitats. There are continental shelves as narrow as 13-18 km along the southern Peruvian and northern Chilean border to as wide as 245 km (500 km) in the case of the Southern Brazilian-Argentinian continental shelf (Falkland Islands) (Araya-Vergara, 2007). As to coasts, calving glaciers and fiord deltas can be found in southern Chile, while coasts supporting mangrove swamps and coral reefs can be found in the Caribbean and northwestern and northeastern coasts of South America, with dune and salt marshes found throughout the region. *Overall, LACs marine ecological space, as with the land seems to have become progressively differentiated over time.*

2.1.3. The cultural context

A clear understanding of the development of the coupled human-environment systems of LAC over historical time is essential for understanding biodiversity patterns and for finding ways to sustainably use and conserve biodiversity.

Pre-Columbian times

Although not for as long as in some other regions of the world, humans have occupied LAC for sufficient time to have affected the ecology and biodiversity of the region. Phylogenetic work has confirmed that Amerindian-like people crossed Beringia at around 19 000 year BP, immediately after the LGM, and were the bearers of a limited number of Asiatic haplotypes (Achilli et al., 2008). The earliest archaeological remains attributable to Amerindians in LAC date back to 14 500 BP (Monteverde, southern Chile). However, there are more controversial and even earlier dates of human occupation in the region. A skull dated at 13 000 BP (the Peñón woman) recovered on the edge of a giant prehistoric lake which once formed in an area now occupied by Mexico City, supposedly has Caucasian characteristics suggesting that either there was a much earlier migration of Caucasian-like people across the Bering Strait and that these people were later replaced by a subsequent migration of Mongoloid people from which Amerindians are descended, or that a group of Stone Age people from Europe crossed the Atlantic Ocean many thousands of years before Columbus or the Vikings and subsequently became extinct. A Brazilian site with a long cultural sequence possibly extending as far back as 32 000 BP and Monteverde, with a possible earlier occupation, dated at 33 000 BP (Dillehay and Collins, 1988), might also indicate earlier occupations, but here further studies are required. Of course, if there has been an earlier occupation, our perception on how pristine LAC ecosystems are today might require revision.

Returning to the Amerindians, initial occupation of the Pedra Pintada Cave near Monte Alegre, Pará, Brazil, by Amerindians, is estimated to be from 11 200 to 10 500 BP, and excavations there have uncovered carbonized tree fruits, wood, and faunal remains, revealing a broad-spectrum economy of humid tropical forest and riverine foraging (Roosevelt et al., 1996). The oldest known human settlement in Amazonia is around 11 000 BP (Denevan, 2007). Archaeological work at Canímar Abajo, Cuba, has confirmed that human groups inhabited the Greater Antilles as early as 7 000 BP (Peláez, 2008).

Prior to European colonization some 400-500 BP, an estimated 55-150 million Amerindians, considered to represent 20% of world population in the 15th century (Chaunu, 1969), inhabited LAC. In general terms, the cultural diversity of the region is one of the most prominent worldwide, as indicated, for example, by the diversity of languages –important because languages are the fundamental element of culture and identity. Thousands of languages were spoken in Latin America prior to first contact with Europeans.

The surviving Amerindians are assembled into 400 groups, representing 34 language families and two special language groups (Montenegro and Stephens, 2006) and represent a mere 1.6% of the world´s population, and 7% of the total population of LAC today. The largest groups of indigenous peoples are today found in Mexico, Guatemala and Brazil and in the Andean countries of Bolivia, Peru and Ecuador. Presently there are 226 groups totaling around 0.6 million persons in Brazil alone (ca. 0.2% of Brazil's population), mostly located on indigenous lands, who speak 180 different tongues. Meso America is a territory of remarkable cultural diversity, as evidenced by the diversity of languages which amount to over 250, 240 of which are present in Mexico (Toledo, 1995). The languages spoken by the 50 distinguishable ethnic groups in Mexico include numerous variants; for example, there are 16 variants of the Náhuatl (Aztec) language, 33 of the Mixteco tongue and 14 of the Chinanteco. Although such cultural diversity is remarkable, it only represents the remnants of an even vaster richness: it is estimated that upon arrival of the Spanish conquistadores, there were about 100 distinct ethnic groups, which suggests that there must have been between 400 and 500 different tongues initially. At the time of European contact there were primarily two groups of Amerindian living in the Caribbean: the Taínos (often called Arawaks), who originally settled in the windwards and leewards and eventually inhabited the Greater Antilles and the Bahamas; and the Caribs who came from Venezuela in South America and lived throughout the Lesser Antilles. *The cultural stamp of the Amerindians, thus deeply permeates LAC.*

The livelihoods of preColumbian Amerindians over a greater part of LAC initially relied on diffuse and spatially wide-ranging relationships with the land and the sea as expressed in hunting and gathering, shifting culture, marine and fresh-water fishing, to evolve in the direction of crop cultivation, animal domestication, the manipulation of forests and other ecosystems for food, goods and services during the Holocene (Stahl, 1996; Toledo et al., 2003) and finally the development of permanent settlements. Some groups, such as the Fuegeans in the extreme south of South America, relied heavily on the capture of marine mammals and the camelid, guanaco. Based on molecular data for the domestication of maize in the Mexican highlands (Matsuoka et al., 2002), it has been estimated that domestication and agriculture developed as early as 9 100 years BP, with subsequent spread to the lowlands, Central America and the northern Andes. In Panama and in the Colombian Amazon several domestic crops were probably being cultivated between 7 000-10 000 BP (Denevan, 2007). Recent work (Dillehay et al., 2007) indicates that peanuts (*Arachis* sp.), squash (*Cucurbita moschata*), and cotton (*Gossypium barbadense*) were cultivated in the Andes between 9 240 and 5 500 ^{14}C years before the present in a tropical dry forest valley. However, the intensity and spatial extent of these different land and marine use types in different parts of the region, and their preColumbian impacts on biodiversity are still matters of discussion (cf. Stahl, 1996). As more evidence comes to light, it would appear that several areas of the Amazon Basin were extensively used. Heckenberger et al. (2008) recently described settlement and land-use patterns of complex societies on the eve of European contact in the Upper Xingu region of the southern Brazilian Amazon, consisting of clusters of prehistoric towns, villages and hamlets, with well planned road networks, and associated manioc cultivation and arboriculture; a type of "garden city". The Amazon forest has subsequently expanded back into these abandoned settlements. These findings lend further support to a growing body of evidence that refutes a totally pristine Amazon.

The archaeological record provides evidence for the use of fire, extensive terracing, irrigation canal systems in arid areas, raised fields and the development of black earth sites in tropical forests during the Holocene (Stahl, 1996). Indigenous peoples used fire not only for clearing land for crops in tropical areas, but also for hunting large birds such as rheas, and mammals such as guanacos in the Patagonian steppe. Archeological and paleobotanical research in Brazil indicates that there was an intensification of practices surrounding plant exploitation and direct human impact on the environment between 10 000 and 8 600 BP (Piperno and Pearsall, 1998). These practices resulted in forms of horticulture emphasizing both native tubers and seed plants, and probably also involved the purposeful planting or management of trees. At some time in the past, a number of native fruit trees were domesticated and incorporated into prehistoric agricultural systems. Apparently the focus of early agricultural systems in the Neotropics was on carbohydrate-rich root or tuber crops, with trees as secondary components (Piperno and Pearsall, 1998). Some of these life styles still characterize indigenous groups today in Mexico, Central America and the Amazon.

The European invasion

Post 1492, as European nations claimed dominion over most parts of the Americas, several commodities from LAC, including gold and biodiversity, came to transform the economies of Europe and diets around the world, respectively. Contrasting with the relatively low level of impact on forests and other habitats by indigenous peoples, the European invasion of LAC of the 16th and 17th centuries set off a wave of ecosystem destruction, to make way for pasture and croplands. By the eighteenth century a variety of colonial styles had emerged in the Atlantic and Pacific nations (Dewald, 2004). Following the end of the gold mining period, African slave labour supplied the most coveted and important items in Atlantic and European commerce: namely sugar, coffee, cotton and cacao of the Caribbean. In Brazil alone it is estimated that 3.6 million African slaves arrived between the 16th and 18th centuries.

Trade factories, plantations, and town and urban settlements were scattered around the western part of the Atlantic Ocean (Dewald, 2004) resulting in the fragmentation of numerous natural ecosystems. For example, the cultivation of the sugar cane, which started in Cuba in 1772-1791, resulted in the widespread felling of trees. In Puerto Rico, by the 1920's more than 90% of the island was deforested, with coffee plantations covering ca. 900 000 acres. At the temperate extreme, in Chile and Argentina, massive burning of forests as a form of frontier expansion and domination ensued in the 19th century. Such destructive land use, fueled by commerce, eventually crept deep into the lowland tropical latitudes of LAC, where it is still rife today, resulting in one of the most serious and complex environmental problems on our planet as seen in the Amazon. Concomitantly, European domination and the spread of sickness greatly reduced the indigenous population.

The 1970s saw the initiation of a second major assault period on LAC´s ecosystems brought on by a move from medium-scale agriculture, forestry and fishing to intensive large-scale enterprises based on a limited number of species. Notable examples for this period are soy bean production in Brazil and Argentina, now contributing to 39% of the world supply (FAO, 2007), sugar cane production in Brazil, stimulated by the need for alternative energy sources (31% of world total; FAO, 2007), pine and eucalypt plantations in Chile, Argentina, Brazil and Uruguay (collectively summing to more than 12 million ha in 2005, and up from 9.8 million ha in 1999; FAO, 2005) –all this often with little regard for maintaining the ecosystem services and biodiversity involved, as will be seen later.

2.1.4. Population trends and urbanization

During the second half of the past century, paralleling changing land use patterns, LAC witnessed a heightened trend for migration into urban areas in search of new opportunities, education and a generally better quality of life. From 1950 to 2005, LAC´s urban population increased from 41 to 77.5%, this contrasting strongly with the overall world tendency (51.4% in 2005). Numerically, this level of migration translates into a six-fold increase in the urban population of LAC in little over half a century.

The present LAC population stands at 579.4 million, which is the equivalent of 8.6% of world population. By 2009, the total human population of LAC, according to predictions, will have increased by over 170 million in relation to 1985. The UN Population Division 2006 estimate for 2050 is 769 millions. According to UN projections the urban population may increase to 88.8% by 2050, bringing it to 682.5 million, a figure which will exceed the entire population of LAC in 2008. At the same time, the projected rural population for 2050 will be lower than in the year 1950. Notably, in a relative sense, there will be proportionately fewer people living in rural environments in LAC than presently occurs in the developed countries.

Significantly in the context of this report, the rush to urban centers in Latin America has strongly targeted the major cities, to the extent that four of the globe's 19 megacities (>10 million inhabitants) recognized by the UN at the turn of the 21st century are now found in LAC (Mexico City, São Paulo, Buenos Aires, Rio de Janeiro). Mexico City has 19.2-22 million inhabitants (depending on source), and São Paulo 19.2-20.6 million, ranking third and seventh respectively among the 10 largest urban agglomerations worldwide. Paralleling the influx of inhabitants into these urban giants, migration from Mexico and other Latin American countries to the USA has increased 15-fold from about 760 000 in 1970 to 11 million in 2004, at a average rate of about half a million per year. The GEO-4 identified the growth of the cities among the main regional problems in LAC. Of the families living in cities, some 39% live below the threshold of poverty. Some 54% of the "extremely poor families" live in cities (United Nations Environment Programme, 2007).

It should be added that at the turn of the 21st century, economic development in LAC still lags behind that in the developed countries and continues to be highly disparate among nations and internally. According to World Bank statistics for 2007, mean per capita GDP per country in 2007 was US$6 680, ranging from a low of $1 050 (Haiti) to a high of US$14 500 (Chile). When differences in population among countries are taken into account, the mean per capita GDP in LAC comes to just over US$9 000

2.1.5. Diagnosis and challenges

From our brief historical and demographic synopsis we see three significant trends in relation to biodiversity science and purposes of this document.

First, it is generally agreed that the extermination and/or reduction of indigenous groups through disease that occurred with the Europeanization of LAC resulted in the loss of significant cultural knowledge on the sustainable use and ecology of biodiversity in LAC, as well as on how the indigenous peoples perceived nature in general.

Second, the frontier mentality of the European colonizers, along with the introduction of Old World agricultural land use practices, supplanted the previous Amerindian social perception of LAC´s natural ecosystems from that of a vital life-support system, to one of an enemy to be tamed and conquered.

Third, the more recent intensification of agriculture and fishing, based on a limited number of genetically-impoverished major crops and trees, along with a trend for migration into major cities, has widened the distance between the human inhabitants of LAC and their natural ecosystems. This last trend is not unique to LAC, but it is notable that it has occurred with extraordinary intensity, in what will be shown to be the most biodiverse region in the world, and whose biodiversity, consequently, has outstanding scientific and socio-economic value.

Fourth, that economic development still lags behind in LAC, at a political level, tends to translate into the perverse notion that present land use practices will be necessary until first world status is achieved. One evident result is that LAC is aggressively seeking international markets across the globe, with many products still being based on the exploitation of natural resources or on the inadequate management of the lands and sea upon which crops/fish are produced. As will be seen later on in this assessment, the unsustainable use of natural resources and ecosystems, considered to be one of the main drivers of the extinction of biodiversity, is far from under control.

The foregoing points raise serious challenges:

- The rescue of local knowledge on biodiversity from culturally diverse LAC needs to be completed before it dissipates under an urban sky.
- The growing urban population must be educated about biodiversity so as to empower citizens when it comes to their rights on environmental matters.
- Economic activities based on the sustainable use of biodiversity as a means for keeping (or returning) people to the land or smaller towns need to be implemented.

It must be driven home to governments that biodiversity loss at any level, from the gene to the ecosystem, cannot be within the region's best interests.

2.2. BIODIVERSITY OF THE LAC REGION

2.2.1. The questions

How much biodiversity does LAC hold, and where is its natural capital concentrated in the Region? Are there reasons to believe that certain parts of the region are more valuable in terms of biodiversity than others and in terms of ecosystem services? Where is LAC situated today in the general field of biodiversity research? What are the main scientific gaps in our knowledge and the principal obstacles for overcoming such gaps?

The answer to the first question is not easy given that the different countries of the Region exhibit widely different levels of scientific development. It seems fair to say that, overall, the main emphasis in biodiversity research in LAC over the past 20 years continues to be on exploration and the documentation of country-level biodiversity, there being, nevertheless notable incursions into other areas of biodiversity science in the more developed countries. The level of basic knowledge is now sufficient to detect sub-regional and regional scale biodiversity patterns and to situate LAC in the global arena. Thus in what follows later, we use knowledge on diversity of *biogeographical divisions*, diversity of *ecosystems*, diversity of *species*, diversity of *life forms* and *functional groups*, concentration of *endemic organisms*, and *agro-biodiversity* associated with cultural diversity to characterize LAC´s biodiversity. Of late, emphasis has been placed on detecting *Hotspots* and *Frontier Forests*. These metrics combine biodiversity descriptors such as richness and/or endemism and ecosystem value with other parameters of interest, such as the degree of threat, or importance in terms of carbon storage, etc. The latter descriptors of biodiversity descriptors could be seen as a prelude to developing even more integrative biodiversity descriptors.

With regard to the areas of biodiversity knowledge, *diversity of interactions*, *molecular phylogenetics*, *genome sequencing*, and the study of the *ecosystem services of biodiversity*, it will be seen that the seeds in each case have been sown.

It will also become evident that knowledge of LAC´s terrestrial ecosystems is far more complete than for its marine and fresh-water ecosystems. In general, the knowledge base on marine biodiversity (*genomes, species, and ecosystems occurring in defined regions*) is inversely proportional to the depth of the oceans worldwide. The hiatus between knowledge on terrestrial versus marine and freshwater biodiversity represents one of the biggest challenges for biodiversity research in LAC.

2.2.2. Diversity of biogeographical divisions and provinces

Biogeographical divisions reflect distal evolutionary history, or what might be called the genetic memory of a region. Considering terrestrial and marine habitats, among the eight major divisions widely accepted by biogeographers (Pielou, 1979), LAC occupies the entire Neotropical Realm, with part of northern Mexico pertaining to the Nearctic Realm. Morrone (2001) produced a comprehensive biogeographic scheme that integrates information on both plants and animals. The latter recognizes three major biogeographic regions in LAC (Neartic, Neotropical and Andean). The Neotropical Region further subdivides into four Subregions (Caribbean, Amazonia, Chaqueña and Paranense), while the Andean Region subdivides into four Subregions (Paramo-Puna, central Chile, Subantarctic and Patagonia). The Neartic Region contains five biogeographical provinces, the Neotropical, 50, and the Andean, 15, giving a grand total of 70 separate biogeographic provinces. There are other biogeographic schemes for LAC –some based solely on plants and others solely on animals, with differing degrees of matching. Irrespective of these differences, which in a sense allude to a specific research problem per se, there can be no doubt that the diversity of biogeographical regions in LAC is very high. This of course, is predictable from the paleogeographic development of the region and the increased environmental compartmentalization that has ensued over the past 100 million years, as addressed earlier.

2.2.3. Diversity of ecosystems

Broad biome-level classifications show that LAC´s terrestrial habitats encompass, with the exception of tundra (a typical boreal biome located north of the taiga), all major biomes recognized on the planet, regardless of the variation in biome nomenclature or classification system. Nevertheless, the outer treeless cushion bog formations on the extreme southwestern edge of South America are considered by some experts as tundra (Pisano and Dimitri, 1973).

Twelve major biomes are present in the region (Figure 1), including the extremes of the precipitation gradient, such as evergreen tropical rain forest in the Colombian Chocó (with annual rainfall of over 10 000 mm), to hyperarid deserts in the Atacama region of northern Chile (with rainfall regimes as low as 0.5 mm on average in the period 1993-1996, or zero rain between 1856-1858). Likewise, terrestrial biomes encompass the entire altitudinal gradient, from sea-level mangroves to "temperate" grasslands reaching altitudes of over 5 000 m. a.s.l. in the puna of southern Peru and Chile. Tropical rain forest occupies 44% of the area (Figure 1), making it the most extensive tract of this biome on Earth. While tropical rain forest reaches its maximum expression in Amazonia, it also extends well into higher latitudes, with the northernmost point of its global distribution in San Luis Potosí, Mexico at 23° latitude N where it is found in ecotone with semi-arid biomes. Next in coverage is the grassland-savanna biome (16.4%), followed by the arid and semi-arid deserts (11.3%), the seasonally dry tropical forest (8.8%) and the temperate grassland and savannas (7.9%). The remaining biomes each cover less than 4% of LAC. Included here are montane grassland and scrub (3.9%), temperate broadleaf and conifer forest (2% combined), and tropical coniferous forest (2.9%). Mangrove forests, although widely distributed in estuarine environments along the inter-tropical coasts, cover a mere 0.6% of the territory, given their spatially restricted and selective environments. Given the diversity of major biomes in the region, it is difficult to find another area of the planet that could parallel LAC's biome/vegetation type diversity, with the exception, perhaps, of the Indian subcontinent –a region of great topographic complexity and environmental heterogeneity that brings about a diverse mosaic of ecosystem types.

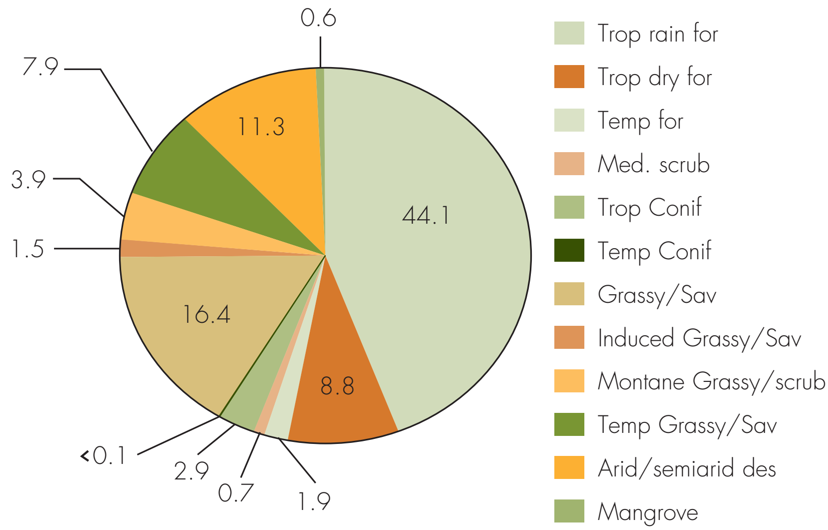


Figure 1. The major biomes of Latin America and the Caribbean (LAC) Region and relative representation of each of them. The codes, given to the right of the diagram, correspond, from top to bottom, to: tropical rain forest, tropical dry forest, temperate forests, Mediterranean scrub, tropical coniferous forest, temperate coniferous forest, natural grasslands/ savannas, induced grassland/ savannas, montane grassland/scrub, temperate grassland/ savannas, arid and semiarid desert, mangrove. Data obtained from numerous sources cited in the literature.

Although the above delineation of biomes is useful for obtaining a general picture of ecosystem diversity in LAC and situating the region in the global scenario, its utility is limited when it comes to looking at finer-grained biodiversity patterns, conservation targets, and ecosystem services at the level of watersheds, given that almost all such major biomes represent a mosaic of variations of the same theme, defining distinguishable vegetation units (from the points of view of physiognomy and phenological rhythms) associated with more particular physical environments. Indeed, continuing in the future to use the broad biome classification could be counter-productive when it comes to assessing conservation needs. An example is seen in the tropical rain forest biome, which is manifest as semi-evergreen rain forest, semi-deciduous forest and palmettos (e.g., *Sabal* palmettos in particular edaphic conditions) in the lowlands, and as cloud tropical forest at higher elevations; yet there are major differences in the conservation efforts among these rain forest types, such that reference to the conservation effort in the entire biome will be misleading. Similar ecological variation is applicable to most other major biomes of the region.

Recognition that biomes are too broad for detailed comparative work on biodiversity in LAC has lead to efforts to classify terrestrial ecosystems at a finer level. Such an initiative is presently being undertaken by NatureServe. Here, Terrestrial Ecological Systems are defined as a group of plant community types that co-occur within landscapes with similar ecological processes, substrates and/or environmental gradients. Ecological Divisions are sub-continental landscapes reflecting both climate and bioegeographic history. Thus far close to 700 different ecosystems types grouped in 23 major Ecological Divisions have been identified, giving 30.7 ecosystems/million km^2 (Josse et al., 2003). The last figure will increase with the inclusion of the Pampas and Patagonia. According to these criteria, in LAC, there are some 512 (71%) predominantly forest, woodland or scrubland, 198 (28%) predominantly herbaceous, savanna or shrub steppe, and 17 (2%) sparsely vegetated Ecological Systems. To situate LAC, using the same methodology, 600 ecosystem types for Canada and the United States of America have been identified on a land area of 19.8 million km^2, giving 30.3 ecosystems/million km^2. The five most diverse Ecological Divisions in LAC, in order of importance are the North-Central Moist Andes, the South-Central Dry Andes, the Guianan Uplands and Highlands, the Caribbean and the Cerrado. The most diverse country in LAC in terms of ecosystem diversity is Bolivia, followed by a number of tropical countries, including Mexico and Peru. Whether this particular scheme will be adopted remains to be seen, and herein a message is contained: a comprehensive ecosystem framework that is useful for multiple purposes in biodiversity research constitutes an urgent need for the region.

From the little distilled information we have been able to find, the diversity of freshwater ecosystems embedded in terrestrial habitats in LAC is outstanding. A conservation assessment of freshwater biodiversity of LAC coming out of a workshop in Bolivia in 1995 implemented by WWF and the BSP (Olson et al., 1998) identified nine major habitat types and 117 ecoregions. Eleven ecoregions (9%) were considered to be globally outstanding, particularly the Amazon river basin, Southern Orinoco, Río Negro, Chihuahuan desert, high elevation lakes of central Mexico, Llanos, Guinea watershed, and varzea flooded forests of the Amazon. Another 51 (44%) of the ecoregions are considered outstanding within the Neotropical realm.

At a large scale, LAC´s marine habitats include the following ecosystems as examples: The Caribbean Sea Large Marine Ecosystem, a semi-enclosed sea that encompasses an area of 2.5 million km^2, and is the second largest sea in the world. It is noted for its many islands. The North Brazil Shelf Large Marine Ecosystem owes its unity to the North Brazil Current, which flows parallel to Brazil's coast and is an extension of the South Equatorial Current coming from the east. It is significantly affected by freshwater and sediments brought by two of the largest rivers of South America, the Orinoco and the Amazon. The East Brazil Shelf Large Marine Ecosystem is dominated by the South Equatorial Current, which has an offshoot along Brazil's North Coast (the North Brazil Current) and to the south (the Brazil Current), and encompasses the Brazilian reefs (Amaral and Jablonski, 2005) as well as the small archipelagos of Fernando de Noronha, an important breeding area for many species of sea turtles (Couto et al., 2003), and Abrolhos, the largest marine park of Brazil covered by corals and immense reeves (Dutra et al., 2005). The South Brazil Shelf Large Marine Ecosystem with a wide continental shelf (up to 220 km), is dominated by the Brazil Current which flows parallel to the coast and is an offshoot of the South Equatorial Current. It encompasses the Cabo Frío upwelling which is important for its productivity (González-Rodríguez et al., 1992), and the estuary of South America's second largest river, the Parana-Paraguay-Prata. Economically this is an important area for Brazilian fishery, mainly when cool, nutrient-rich South Atlantic Central Water (SACW) penetrates into the coastal areas (Matsuura, 1998). The Patagonian Shelf Large Marine Ecosystem, with an area of about 2.7 million km^2, extends from Uruguay to the Straits of Magellan, with a continental shelf that widens progressively to the south, where it reaches a width of about 850 km. It is influenced by two major wind-driven currents: the northward flowing Falklands/Malvinas Current and the southward flowing Brazil Current (Bakun, 1993). Again, as for terrestrial ecosystems, these large scale ecosystem units are useful for global comparisons, but their utility becomes limited at finer scales.

For South America a recent study has recognized 28 main Marine Ecoregions (mostly based on coastal systems) (Chatman, 2007) (Figure 2). These are: a] two

Figure 2. Marine ecosystems in Latin America and the Caribbean.
From Chatwin (2007).

marine Ecoregions for the southern sector of the Caribbean seas: b] 15 marine Ecoregions for the Atlantic, and; c] 11 marine Ecoregions for the Pacific. These marine ecoregions include rich and complex marine habitats ranging from tropical coral reefs found mainly in the Southern Caribbean Ecoregion in Venezuelan and Colombian waters. Strong riverine influences along the coast of Brazil in the Guianan and Amazonian Ecoregions are reflected in extensive and faunistically-rich mangrove coastal habitats. A similar situation is observed in the central Pacific coast in Panama, Ecuador and part of the Galapagos. Central Atlantic Ecoregions are characterized by the presence of coral reefs and the influence of the Orinoco and Amazon rivers. From the offshore fishery point of view the area is characterized by low productivity waters. The southern Atlantic tip of South America presents temperate and subantarctic rich fisheries and extensive coastal marine platforms, while the Pacific side is characterized by interior seas, fiords and pristine channel systems. The central and northern part of Chile and the Peruvian coast embrace several Ecoregions; one of the most distinguishing characteristics here is the presence of upwelling active systems (Humboldt System) and high productivity, already mentioned.

2.2.4. Diversity of species

After several centuries of exploration by professional scientists and naturalists within the countries of LAC and from many other corners of the world, one would like to be in a position to say that the exploration of LAC´s biodiversity at the basic level of the discovery of species is complete. However, the truth is that our knowledge of species richness patterns for many groups of organisms in LAC is still incomplete. Often, moreover, the taxonomic information is not organized in such a way so as to be useful for global, regional and subregional comparisons. Much taxonomic information often exists but it has not been converted into electronic form. Where it has been done so, excellent results have been forthcoming (e.g. Soberón et al., 2000). At the other extreme, some important electronic georeferenced data bases in very good shape in the region are still not available online, hindering the scientific effort. On the brighter side, because many collections were made over the last 25 years in LAC, high proportions of specimens in many countries are furnished with georeferences, a notable exception being Argentina, which was intensively explored at a much earlier stage. The importance of georeferenced data bases in biodiversity research cannot be over stressed.

One of the main obstacles here is that the organization of georeferenced data bases requires enormous efforts on the part of smaller herbaria and museums, for which citation benefits are not reaped, given that such data bases do not constitute scientific publications. Without citations, research funding is becoming increasingly difficult in LAC, leading to a vicious circle. The argument that it should not be required to place georeferenced specimens online until they have served their original purpose of producing the flora/fauna of a country or region is often espoused throughout LAC. This whole area of access to biodiversity data bases is a critical aspect for the future of biodiversity research in LAC.

Another blatant obstacle in LAC concerns the lack of taxonomists –personnel/scientists who are capable of using a technical key to identify a plant and write taxonomic treatments. In his paper engagingly titled "Biodiversity and a taxonomy of Chilean taxomists", Simonetti (1997) showed that the Chilean community of taxonomists is down to a minimum, there being no taxonomists at all for several groups of organisms. We estimate 0.004 persons/species are able to competently identify vascular plants in Chile; several are retired or near retirement. Shepherd

(2006) is of the opinion that without a major effort to change this scenario the flora of the Amazon region will remain vastly unknown. A repeat of the situation in the Coast Range in the central Chilean Hotspot, where plantation forests have obliterated large areas of the native vegetation such that there is not much left to be found, at the scale of the Amazon would be extremely unfortunate for the world. Costa Rica has successfully solved its lack of manpower at the level of collecting by engaging parataxonomists (Janzen et al., 1993). Parataxonomists are a subset of a more inclusive group, known as parabiologists. Well trained, parabiologists can perform useful tasks and perhaps should be engaged more frequently in LAC. In Brazil, scientists have facilitated local people to monitor the populations and phenology of prized fruit-tree species in the forests (Shanley and Gaia, 2002). However, when a country´s stock of taxonomists reaches an all time low, professional man power becomes insufficient to train parataxonomists and other kinds of parabiologists.

Knowledge on biodiversity, as any biologist knows, is strongly scale dependent. Considering LAC´s terrestrial habitats, the less numerous and more conspicuous vertebrate groups are relatively well known at the regional (and country) levels to the extent that informative online data bases (e.g. InfoNatura, www.infonatura.org) are available. This data base provides distribution maps, conservation status and taxonomic information for over 5 500 species of birds and mammals in LAC (Kareiva, 2001). NatureServe´s complementary data base provides high quality distribution maps based on georeferenced data for endemics.

Knowledge on taxonomic composition and species richness for vascular plants at the country and regional scales has improved notably over the past 15 years thanks to the large contingent of botanists and ecologists and intensive exploration programs, but continues to be variable across the region. In South America, the outstanding taxonomic school in Argentina has produced excellent annotated checklists for this country, and in collaboration with other Latin American institutions and the Missouri Botanical Garden has just completed a floristic catalogue for the entire Southern Cone, which includes Argentina, southern Brazil (the states of Paraná, Santa Catarina and Rio Grande do Sul), Chile, Paraguay, and Uruguay (Zuloaga et al., 2008). This ground-breaking piece of work includes nearly all of the subtropical, temperate, and cold-temperate areas of South America from the Atlantic to the Pacific Ocean (4.7 million km^2, the equivalent of 26% of the total land area of South America), and registers 17 692 accepted species, of which 43.5% are endemic. Other regional checklists and floras in the LAC area are well underway, such as the *Flora of Mesoamerica*, while complete checklists are already available for Peru, Ecuador, Chile, and Panama, with another expected in the near future for Bolivia. One gaping hole that persists in LAC is the lack of a published annotated checklist of recognized names for the immense and diverse flora of Brazil (Giulietti et al., 2005a, b). Production of such a list should be a priority in the research program.

For invertebrates and marine organisms (including algae), we still do not have regional, and often not even country checklists in most cases (published or in the Web), even considering the more conspicuous groups, like bees, which are the pollinators of thousands of plant species, and a ecosystem service for cultivated crops in LAC. The same can be said for aquatic insects and many groups of ecologically important beetles, which are known to be valuable as environmental indicators. Country treatments for macrofungi can sometimes be found. By searching through the international literature such lists could definitely be produced in many groups with some time and effort, providing much needed basic information for ecological and climate change work.

As far as we can tell, Chile (Simonetti et al., 1995) and Brazil (Lewinsohn and Prado, 2005) are the only LAC countries where compilations or estimates of the total number of described species across all groups have been published (excluding microorganisms in the case of Chile). Brazil has an estimated 170 000-210 000 described and recognized species (Lewinsohn and Prado, 2005) but is believed to have a total of 1.8 million species, indicating a huge amount of basic work still to be done. In Chile, a mainly temperate country, on a land area equivalent to 9% of Brazil, some 30 000 valid and recognized species have been described (Simonetti et al., 1995).

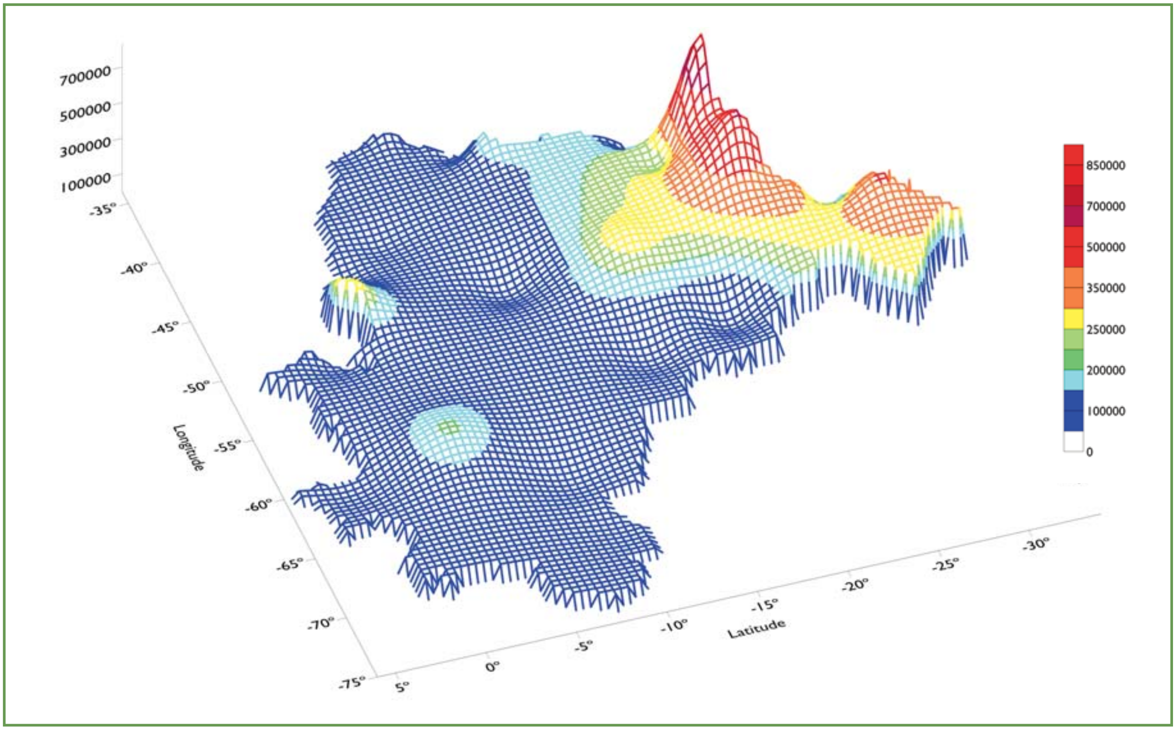


Figure 3. Brazil showing highly unequal sampling efforts of higher plants across states and biomes. From Shepherd (2002).

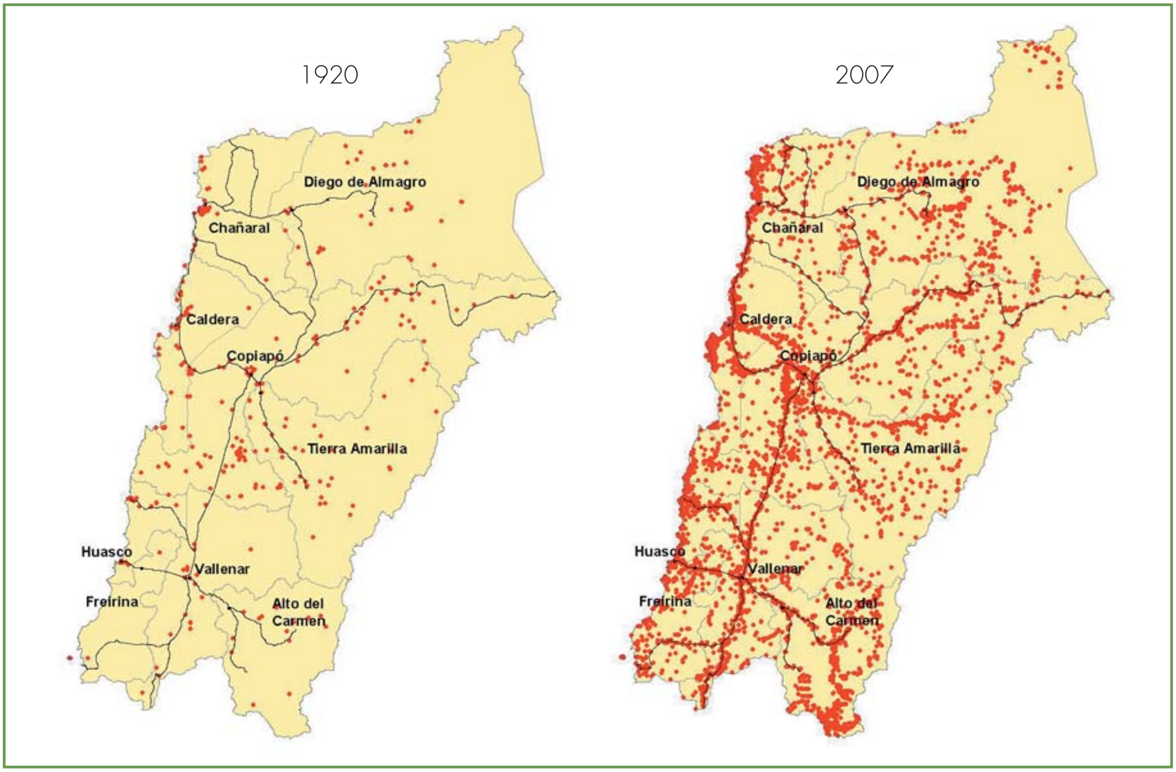


Figure. 4. Comparison of sampling efforts for plant species in the Atacama (III) Desert Region of Chile, showing sampling at two different moment in times. Each point refers to a collection. (Squeo et., 2008).

From the country-level down to the individual plot level, accurate knowledge on species richness in LAC is hindered by collecting density, which can vary greatly between and within countries. An early quantified study in Chile showed a highly irregular pattern of species richness as detected from herbarium specimens in two major herbaria, with enormous gaps persisting in some parts of the country. Unfortunately, some of these exploration gaps will never be adequately filled with real data, because the natural vegetation is now practically obliterated (Ricklefs et al., 1995).

In Brazil, in the year 2000, there were more than 600 000 herbarium specimens for the Amazon region giving an average of 0.133 specimens/km^2, while in the southeastern part of the country (São Paulo, Rio, Minas Gerais and Espirito Santo) there were approximately 1.7 million, averaging 1.8 specimens/km^2 (Shepherd, 2006). However, even though the southern states of Brazil are well collected, the collecting effort is strongly concentrated around the larger cities (Figure 3). Again, the importance of georeferenced data bases (with digital images) for completing the exploration effort cannot be over stressed. Such data bases allow streamlining the collecting effort, filling in gaps, and avoiding duplication in sampling effort, as seen in the notable progress in comparing floristic knowledge for the vascular flora of the Atacama Desert region of Chile between 1970 and 2006 (Figure 4).

Regional species diversity

Notwithstanding the above limitations, knowledge is sufficient to claim that LAC has significant fraction of the planet's species richness. Overall, the available information for terrestrial habitats shows that no other continent is as diverse as LAC. In Figure 5 (upper panels) we show a synthetic and compelling view of such diversity in a global perspective by considering the number of species of vascular plants and vertebrates, as compiled by UNEP's World Conservation Monitoring Center from numerous sources. Vascular plant diversity (Figure 5) makes this particularly evident: countries with floristic contingents of more than 17 300 species are more frequent in LAC than in any other continent and, collectively, LAC harbors a contingent

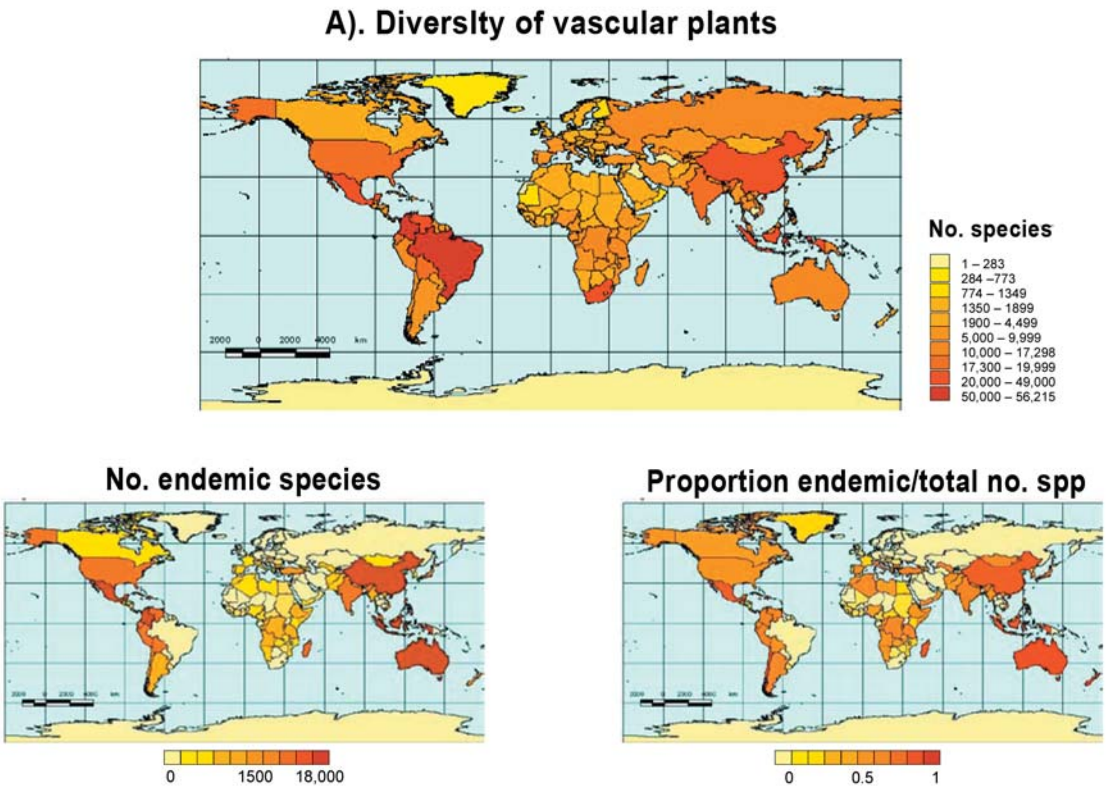
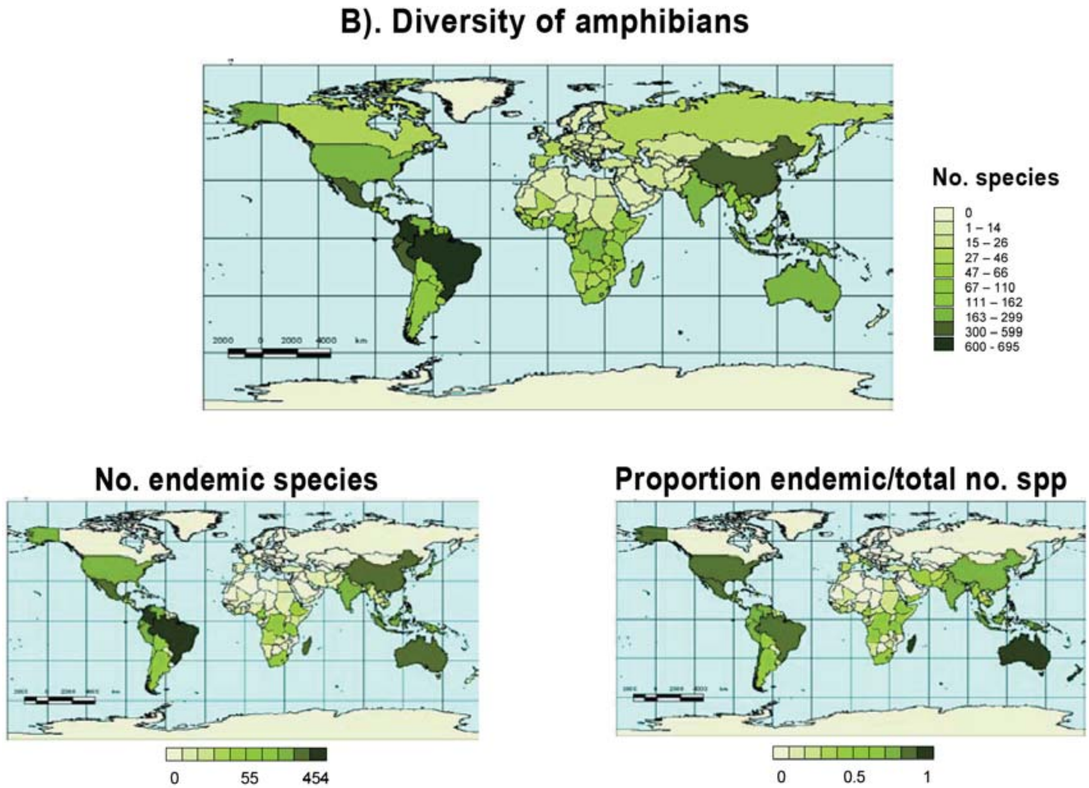
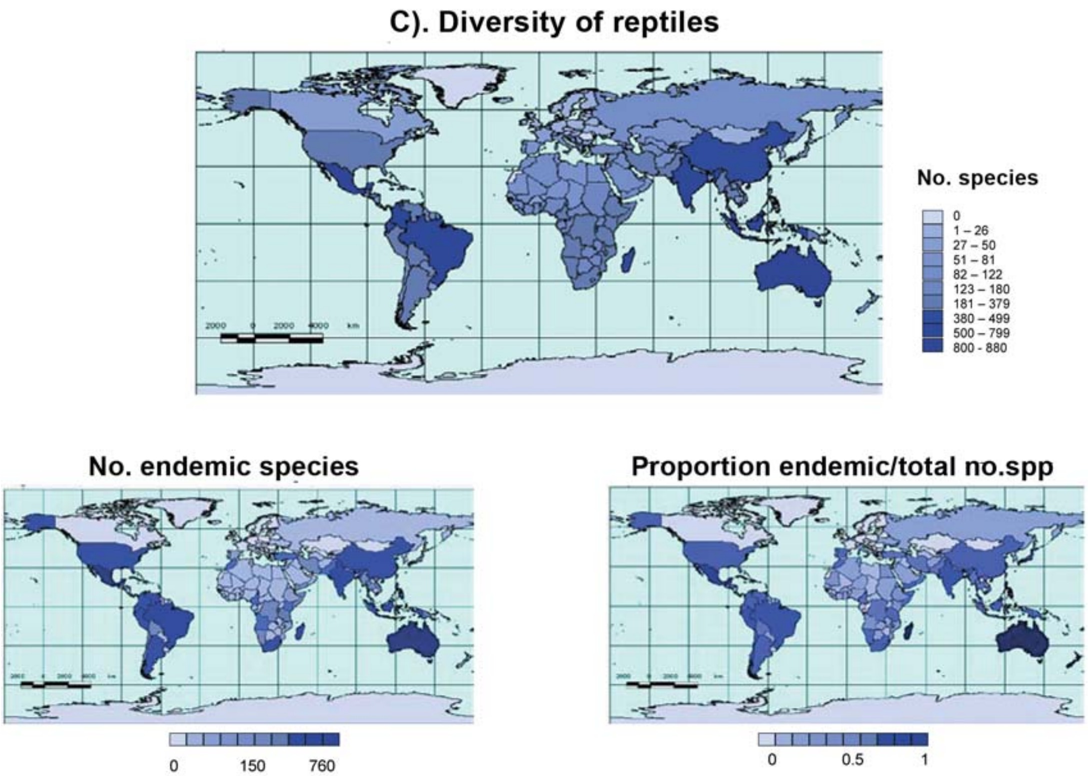
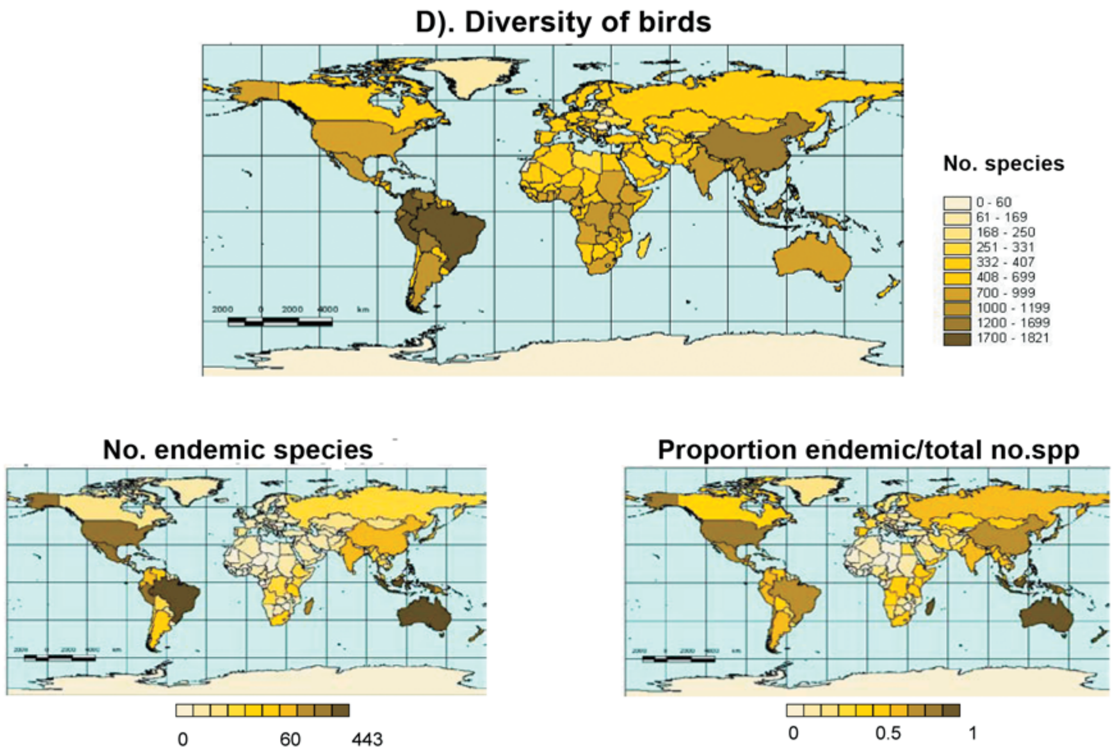


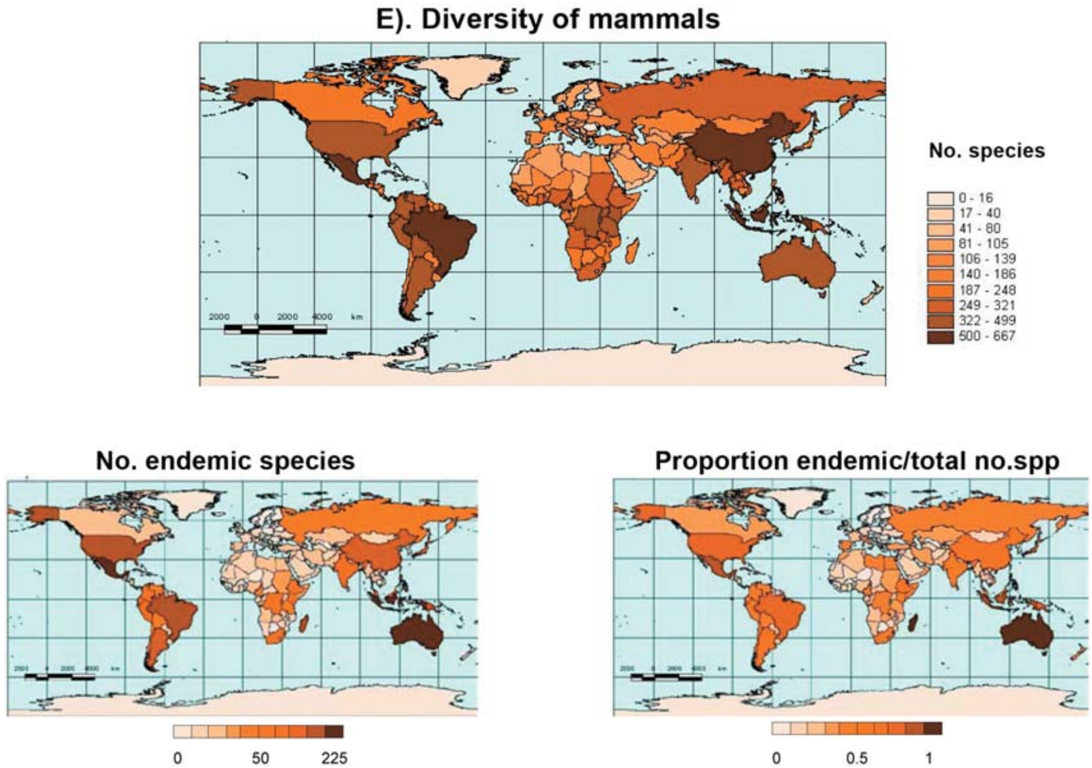
Figure. 5. Global distribution of species richness (number of species per country) of vascular plants (A), amphibians (B), reptiles (C), birds (D) and mammals (E). Maps were modified from those produced by the World Conservation Monitoring Center.


B). Diversity of amphibians
No. species
0
1 – 14
15 – 26
27 – 46
47 – 66
67 – 110
111 – 162
163 – 299
300 – 599
600 - 695
2000 0 2000 4000 km
No. endemic species
0 55 454
Proportion endemic/total no. spp
0 0.5 1



C). Diversity of reptiles
No. species
0
1 – 26
27 – 50
51 – 81
82 – 122
123 – 180
181 – 379
380 – 499
500 – 799
800 - 880
No. endemic species
0
150
760
Proportion endemic/total no.spp
0
0.5
1


D). Diversity of birds
No. species
0 - 60
61 - 169
168 - 250
251 - 331
332 - 407
408 - 699
700 - 999
1000 - 1199
1200 - 1699
1700 - 1821
2000 0 2000 4000 km
No. endemic species
0 60 443
Proportion endemic/total no.spp
0 0.5 1


E). Diversity of mammals
No. species
0 - 16
17 - 40
41 - 80
81 - 105
106 - 139
140 - 186
187 - 248
249 - 321
322 - 499
500 - 667
2000
0
2000
4000
km
No. endemic species
0
50
225
Proportion endemic/total no.spp
0
0.5
1

of perhaps as many as 95 000 species of vascular plants (32% of the world total of 300 000 on 9.6% of the total land area), considerably more than in Asia (35 000) or Africa (45 000), and even greater than the combined values of these two. Such a concentration of countries with high species richness is insinuated only by South Asia, as well as in extensive China. Similar pictures emerge for the mammals, amphibians, reptiles, and birds (Figure 5).

Outstanding diversity is seen in some vertebrate groups in South America, where the information at the level of the continent is more complete than in plants. For example, of the currently recognized 5 154 species of anurans, at least 1 651 (32%) are found in South America, represented by 12 families, four of which are endemic. South America holds close to 20% of all of the world's reptiles and nearly 33% of all birds. Colombia alone has 19% of the world's avifauna and 25% of the world total for terrestrial mammals (reviewed in Meserve, 2007). Considering that 75% of the South American tropical mammal fauna became extinct at the end of the Pleistocene (Meserve, 2007), extant mammal diversity is notable; one of the most fascinating questions concerns what has driven this level of diversification. The Neotropics are estimated by some authors to have 8 000 species of fish, with 2000 in the Amazon Basin alone (Meserve, 2007). Fishes comprise 22 000 of the 43 000 to 46 500 species of vertebrate as estimated by Goombridge (1992). Even if we allow for an eventual 50% increase in the number of recognition fish species worldwide, both marine and freshwater (to approximately 33 000 species), South American freshwater fish (8 000 species) constitute 24% of all fish worldwide. In addition, freshwater habitats represent less than 0.01% of the world's water, with the freshwater system of the Neotropics encompassing 25-28% of that total, or 0.0025-0.0028% of the total water on Earth. In other words, Neotropical freshwater fish, constitute approximately 24% of all fish species, and 1/8th of all vertebrate biodiversity, and occur in less than 0.003% of the world's water (Vari and Malabarba, 1998; Sabino and Prado, 2006).

The number of experts on freshwater biodiversity in LAC must surely bears no relation at all to the level of diversity seen, to the extent that it was impossible to find a fresh-water specialist for LAC for this assessment.

Similar trends for species richness are obtained if the analysis is based on the number of species per sampling effort, as is the case with plants (see below), and

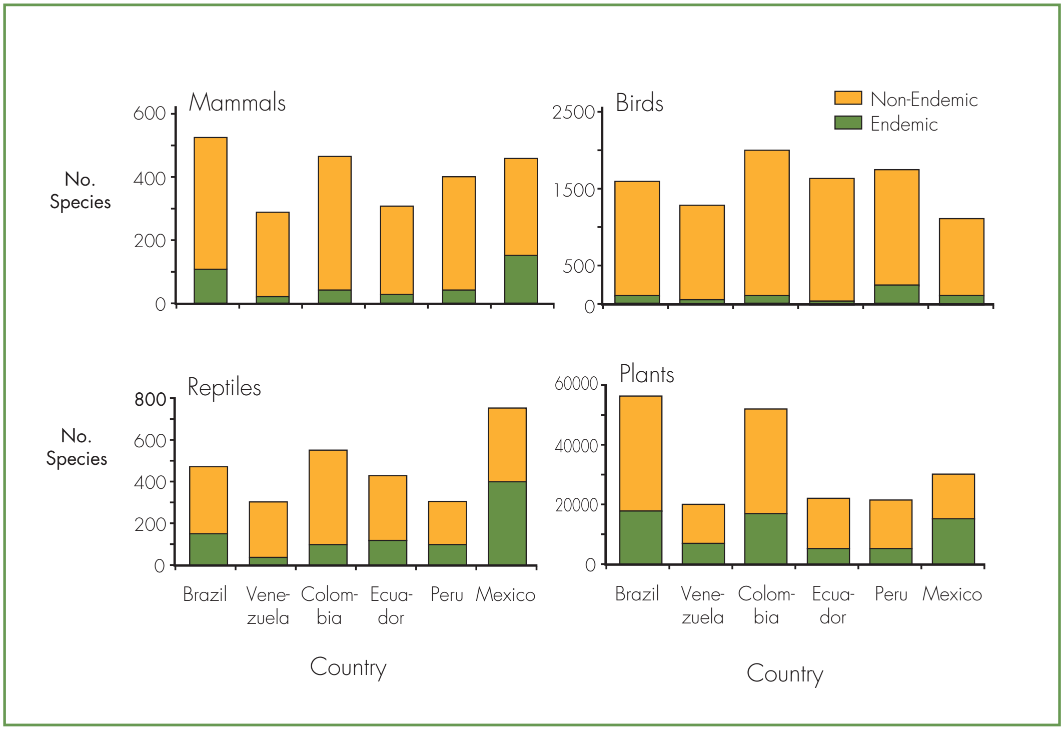


Figure 6. Species diversity and endemism (number of species) of three major groups of vertebrates and plants of six Latin American nations (from left to right: Brazil, Venezuela, Colombia, Ecuador, Peru, Mexico) regarded as megadiversity countries. Data obtained from several sources cited in the literature.

bats among the mammals, or butterflies and beetles among the insects. For example, canopy fogging, a technique used to estimate arthropod diversity and make reliable comparisons across sites, shows species densities of 1.17 and 1.15 species/m^3 in samples from Panama and Peru, respectively, which are considerably higher than densities of 0.29 in Papua New Guinea, or 0.02 in Australia (see details in Dirzo and Raven, 2003).

Figure 6 highlights those countries that consistently have high levels of species diversity for vascular plants and vertebrates. This assemblage of countries comprises Brazil, Colombia, Ecuador, Peru and Venezuela in South America, and Mexico in Central America. This situation underscores another perspective of the importance of LAC at the global level, namely its concentration of so called Mega-diversity countries (Mittermeier et al., 1977; Sarukhán and Dirzo, 2001). Five LAC countries belong to the elite of the 10 most important Mega-diversity countries, and all six are among the 15 most important of this special group. The numbers are remarkable: Brazil, with ~55 000 plant species, Colombia ~50 000 species, and Mexico, ~30 000 species, contain 18%, 16.7% and 10% of the planet's floristic diversity, respectively (estimated to be about 300 000 species). Brazil with more than 500 species of mammals harbors close to 12% of the global mammalian diversity, and Mexico with 440 species contains 10% of the global total. The ranking among these countries varies depending on the group of organisms being considered, but Brazil is prominent in plant and mammal diversity with its plant diversity superseding that of Asia or Africa; Colombia is number one in bird species richness (~1 850 species) and second in plants and mammals; Peru is also particularly rich in birds (second position), and Mexico is first in reptiles and second in mammals. These rankings of course, are influenced by the surface area of each country. This highlights the cases of Ecuador and Venezuela that, despite their relatively small areas, are also placed

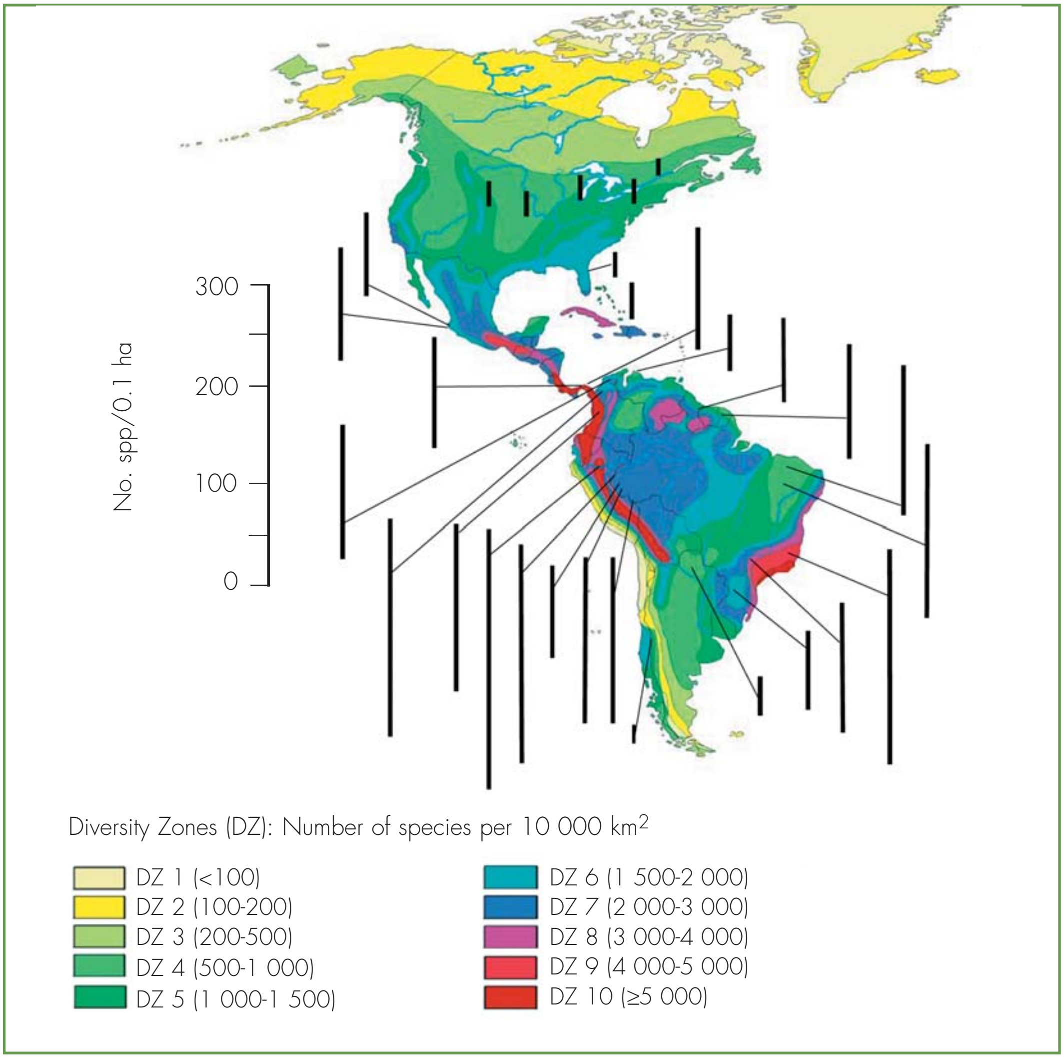


Figure 7. Map of plant species diversity by density surfaces (number of species per 10 000 km^2) in the Americas and the number of plant species per 0.1 ha in different localities throughout the region. Each bar represents the average value for lowland sites (up to 1 000 m above sea level). The number of species per 0.1 ha was obtained from data of Alwyn Gentry (in Phillips and Miller 2002). The map was modified from Barthlott et al. (1999). Figure reprinted from Dirzo and Raven (2003).

among the biodiversity elite, due to the diversity of birds, mammals and reptiles in the case of Ecuador, and birds, mammals and plants in the case of Venezuela.

It is instructive to consider species distributions independently of political boundaries, recognizing at the same time that richness information on a country basis is essential from the geopolitical and policy perspectives. The map in Figure 7 shows two aspects of plant species diversity: i] isolines of plant species density in terms of species per 10 000 km^2, estimated from 1 400 studies compiled by Barthlott et al., (1999); and ii] species diversity at the local scale (Alwyn Gentry's collection of data from 0.1 ha plots, obtained from Phillips, and Miller, 2002; see details in Dirzo and Raven, 2003). Isolines suggest a latitudinal gradient in which species densities range from over 5 000 species per 10 000 km^2 in tropical regions, to less than 100 at the highest latitudes. The isoline approach again highlights the occurrence of high-diversity centers, including western Amazonia, Brazil's Atlantic Coast, and Central America. In terms of local species diversity (plant species per 0.1 ha) values range from an average of almost 300 species in sites located in Peru and Ecuador, to ca. 15 in Patagonia. Both analyses also underscore the importance of areas such as Western Amazonia, which in addition holds the world's record for plant species diversity - one study on large woody plants (girth at breast height of 10 cm or more), found 300 tree species in a total of 360 sampled trees *within a single hectare* in Ecuador (Valencia et al., 1994), implying that almost every single sampled stem belonged to a different species. The global map of plant species richness recently published by Kreft and Jetz (2007), which takes species density into account, makes it more than evident that LAC is one of the biologically-richest areas of the world.

Finally, it must be recalled that the information base for terrestrial invertebrates, algae, bryophytes, fungi and microorganisms is either not organized in such a way so as to be useful for comparisons, or is totally inadequate. Some of these same taxonomic groups of course, play a disproportionate role in ecosystem functioning.

Turning now to marine biodiversity, our knowledge in LAC is either deficient or not available in a format that is useful for this kind of assessment. Only a few data bases exist; thus it is very difficult at the moment to pull exact information on species richness together for the region at any scale. The development of such data bases, clearly, should be a regional priority in marine biodiversity research, given their power for analytical work and for streamlining exploration needs. A few countries in LAC have estimates of marine biodiversity or of some groups thereof. As examples, free-living benthic marine invertebrates in Chile total 4 553 species (Lee et al., 2008) constituting 2.5% of the world marine invertebrate benthic fauna. Surveys off the coast of southeastern Brazil have revealed 1 300 benthic animals, and 617 species of marine and estuarine demersal teleosts, but these numbers are likely to be under-estimated because of inadequate sampling (Amaral and Jablonski, 2005). The coasts of Brazil have around 539 species of macroscopic marine algae (Giulietti et al., 2005a, b), while the Pacific coasts from the subantarctic to Peru, and including island territories belonging to Chile have at least 380 species of benthic algae. Clearly these last richness values are not outstanding when compared with terrestrial plants.

A first estimate of marine biodiversity in Venezuela suggests a minimum of 2 697 species for those coasts (Miloslavich et al., 2003). The Caribbean is among the top five world hotspots for marine and terrestrial biodiversity (Rivera-Monroy et al., 2004). Considering only Cuba, the major archipelago of the Greater Antilles, the total number of registered marine species is ca. 7 300. Some 5 700 are invertebrates, 1 060 vertebrates and the rest algae and micro-organisms (Claro, 2007). In any case, even for the best known marine groups we know very little about their basic biology, ecology, geographic distributions and anthropogenic threats. In LAC microbial diversity assessments from marine systems are very limited, representing a huge information gap (Miloslavich, 2008). Coral reefs constitute unique microcosms of biodiversity. Around 30 000 taxa have been described for Caribbean coral reefs, most of them macroscopic organisms. However, this number is likely to be a small fraction of the total biodiversity. Overall, a huge effort will be needed in the countries of LAC to bring this very basic level of knowledge for marine biodiversity up to that for vascular plants and vertebrates in terrestrial ecosystems.

Latitudinal patterns in species richness

The general global tendency in terrestrial ecosystems is for plant and vertebrate richness to decrease with increasing latitude. In LAC, this fact has tended to underpin a tendency to place greater emphasis on biodiversity research and funding in the tropics, at the detriment of the temperate countries. The classical latitudinal gradient in species richness is evident in some groups of organisms in LAC when the entire region is considered (Figures *5, 7*). However, although there is a significant relationship between latitude and local diversity at the scale of 0.1 ha, the predictive power of this relationship is only moderate (R^2 = 56%; Dirzo and Raven, 2003), indicating that other factors (e.g. area) independent of latitude intervene in determining the observed distribution of plant diversity in LAC. While there are more species in the tropics for vascular plants and vertebrates in general in LAC, recent work has shown that the typical latitudinal decrease in vascular plant species richness in southern South America is accompanied by an inverse trend in richness for bryophytes to the extent that the southwestern coast of South America is a remarkable biodiversity hotspot for bryophytes (Rozzi et al., 2008) (Figure 8). A departure

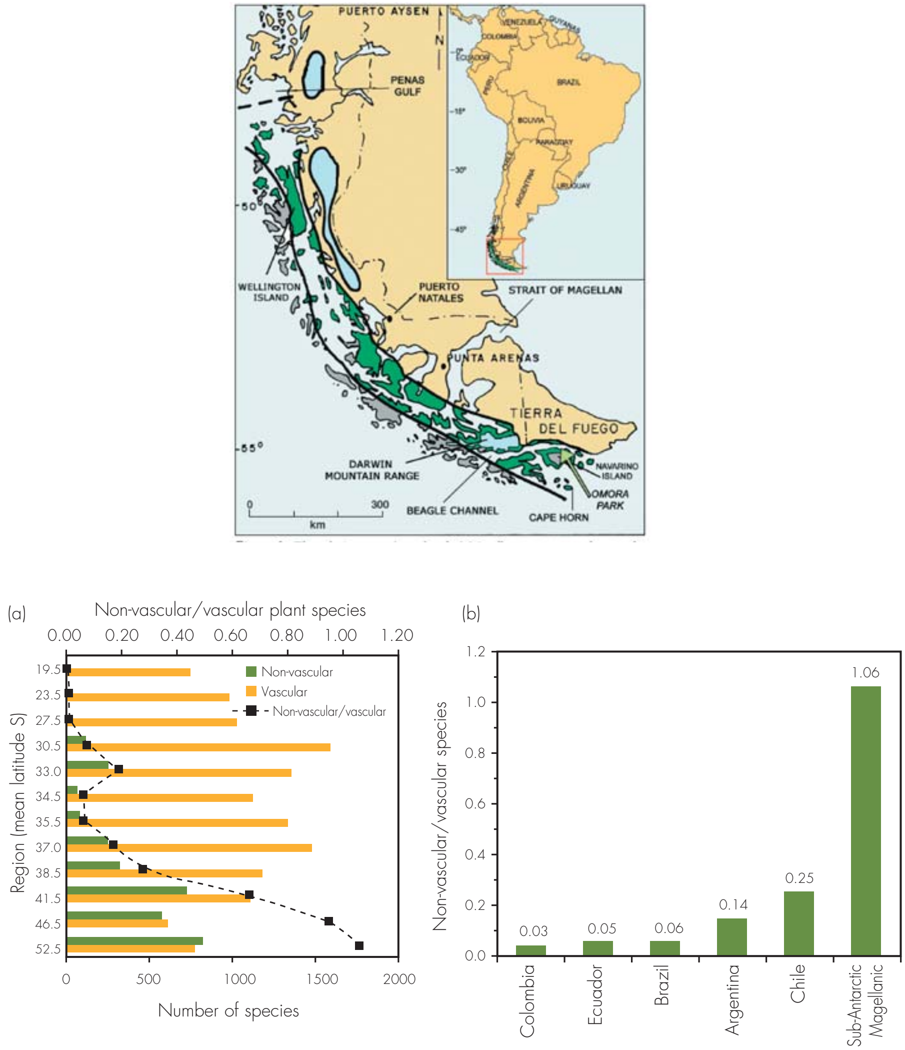


Figure 8. Species richness patterns in nonvascular versus vascular plants in western South America, along with the ratio of nonvascular to vascular plants in different countries in South America. Bryophyte richness increases with latitude, contrasting with vascular plant richness (Rozzi y cols., 2008).

from the more typical latitudinal trend can be expected in other groups of organisms. For example, outstanding diversity in bee pollinators has been found in the lower alpine in mediterranean Chile (Arroyo et al., 1982), yet there are very few bee pollinators in tropical páramo (González and Engel, 2004). Thus care must be exercised when extrapolating on the basis of vascular plants and vertebrates. Given that LAC straddles the tropics and abuts on Antarctica, knowledge on latitudinal trends in biodiversity in many of the more poorly studied groups is vital to increase our scientific understanding of latitudinal diversity patterns in general.

A latitudinal decrease in species richness is not always the manifest macroecological pattern in LAC´s marine habitats as seen for marine mollusks species along the Southeastern Pacific American shelf between 10-56°S (Valdovinos et al., 2003). The number of species here remains constant and low at intermediate latitudes and increases sharply towards higher latitudes, south of 42°S. In the southern hemisphere, marine mollusk radiation may have been limited by narrower continental shelves between 10-41°S. An analysis of marine benthic algae for the Pacific coast of South America (Santelices and Marquet, 1998) likewise showed higher diversity at the higher latitudes. Studies focusing on the latitudinal gradient in species richness have yet to be performed for the Atlantic coast of LAC. However, copepods assemblages analyzed at the generic level along the Atlantic coast of Brazil and Africa together are richer towards tropical latitudes (Woodd-Walker et al., 2002) indicating that the Atlantic pattern might be different.

Alpha, beta and gamma diversity

Additional insights on LAC´s biodiversity may be obtained by considering alpha and beta diversity. As indicated earlier, LAC has many sites with remarkable α-diversity; the maps in Figures 5 and 7 also show the overall regional diversity at the region's large geographic scale, or gamma diversity. However, these maps do not allow exploration of the extent to which the latitudinal gradient or the overall species distribution is explained by species turnover, that is, the exchange of species from one locality to another (β-diversity). An analysis of species turnover requires the identification of species from locality to locality and examination of their exchange across space. This aspect of species diversity provides important information for conservation planning. For example, if local sites have a high α-diversity, but all share the same species, establishment of one or a few protected areas would secure the conservation of those species. On the contrary, if species turnover (β-diversity) is high, securing the conservation of those species would need many reserves. This critical aspect of biodiversity needs to be analyzed for LAC in general. Several isolated studies suggest that β-diversity is high, at least in some tropical areas. For example, a recent study (Trejo and Dirzo, 2002) comparing species composition among 20 tropical dry forest sites in Mexico shows that 72% of a total of 917 sampled species were present only in a single site and that the average similarity (Sorensen's index) among sites was only 9%. While this underscores the high species diversity on a regional level, it highlights the challenging situation of conservation planning of seasonally dry forest plant diversity in LAC. Again, it should be born in mind that all these analyses are limited to vertebrates and vascular plants.

Ecosystem level

Knowledge of species richness (beyond crude numbers) at the ecosystem level is perhaps the hardest information to find insofar as basic biodiversity accounting goes in LAC. Thus far, accurate data of this nature is available for Mediterranean ecosystems in South America (plants, vertebrates and some insects) (Arroyo et al., 1999), vascular plants of temperate forests of southern South America (Villagrán and Hinojosa, 1997), and vascular plants of the páramos (Luteyn, 1999). A checklist of vascular plants for all above treeline habitats (páramo, puna and south temperate alpine) along the length of the South American Andes is in well along the way (Arroyo et al., 2008). Good information also exists for the Brazilian Cerrado, one of the planet's most diverse savanna ecosystems. The Cerrado flora contains 951 species of trees and large shrubs (Ratter et al., 2003) and more than 4 000 herbaceous species without considering the "Campos Rupestres" found above 1 000 m.a.s.l. in the Serra do Espinhaço complex (Mendonça et al., 1997). The "Campos Rupestres" have an estimated 5 000 herbaceous species, being the center of origin of large families like Eriocaulaceae, Velloziaceae and Xyridaceae (Giulietti et al., 1997); many of these species are shared with the more typical Cerrado variant.

Information is available for some large wetlands in LAC. For example, the Patanal, in Brazil, is the home of some 1 863 plant species and 263 fish species, 35 reptile species, 463 bird species and 132 mammal species (Alho, 2005). Certainly, these kinds of data could be obtained for other ecosystems in LAC by tediously sifting through hundreds of published monographs.

Unusual biodiversity in unusual habitats

Given its physiographic diversity, varied geological composition and well developed volcanism, LAC has many unusual habitats which are waiting to be studied. Such habitats are likely to reveal organisms having unusual functional and physiological characteristics that in some cases could be of potential economic benefit. Indeed, there have been some interesting discoveries. In the Minimum Oxygen Zones (OMZs) unique anoxic/hypoxic ecosystems exist. These contain giant bacteria, (*Thiploca)*, Archaea and unique plankton species. The sediments of the Oxygen Minimum Zone of the eastern South Pacific were the first to reveal massive populations of large, free-living bacteria (Gallardo, 1997), now known to belong in the Gamma Proteobacteria, and which were subsequently found along the OMZ of the eastern Pacific OMZ and in sediments under the OMZ off Namibia in the Benguela Current Ecosystem. Gallardo and Espinoza (2006) suggest that such extant megabacteria and their mats may represent analogs of those existing in Precambrian oceans. They potentially provide opportunities for research on the evolution of early life in the ocean's shelf sediments.

Microorganisms have been poorly sampled worldwide, yet are likely to represent an incalculable source of genomic innovation and material for answering basic research questions. Such organisms are found in abundance in the deep oceans and ocean vents, hot springs, the rhizosphere, and on leaf surfaces (the phyllosphere). These habitats, which, as mentioned earlier, are well represented in LAC, as expected, are revealing fascinating findings. A recent study of phyllosphere bacteria on nine tree species in the Atlantic forest of Brazil showed that about 97% of the bacteria are unknown species and that the phyllosphere of any one tree species carries between 95-671 bacterial species, with modally different suites of species being found on each tree species (Lambais et al., 2006). Extrapolation of the results led to an estimate of 2-13 million new bacterial species in the Atlantic forest alone. Questions such as what controls host specificity, whether functional groups can be recognized among bacteria, whether phyllosphere bacterial diversity decreases with latitude and altitude, and whether high tree diversity leads to exaggerated bacterial diversity, immediately come to mind.

Continuing with unusual habitats in LAC, microbial communities from Cuatro Cienegas in the Chihuahuan desert in Mexico, a system of springs, streams and pools, have been found to contain 250 different phylotypes (38 globally unique), with 50% of the phylotypes most closely related to marine taxa (Souza et al., 2006), raising the question as to what is it that the marine and Chihuahuan desert environments have in common. Likewise, hyper saline microbial mats from Guerrero Negro, Baja California have revealed 752 species in 42 of the main bacterial phyla, including 15 novel candidate phyla (Ley et al., 2006). In contrast, the Mars-like soils in hyperarid areas of the Atacama desert completely lack soil bacteria and in the less arid areas where desert bacteria are present, there is less diversity than for equivalent rainfall amounts in the Sonoran desert (Navarro-González et al., 2003). Finally, an assemblage of thermophilic bryophytes growing on volcanically active sites in the Shetland Islands (Antarctica) (Smith, 2005) provides yet another example of unusual biodiversity in the LAC region. These are just a few examples of unusual habitats in LAC. In any case, in any integrated LAC biodiversity research strategy, unveiling the biodiversity of these habitats should be encouraged.

2.2.5. Functional diversity and traits

Functional diversity is independent of the taxonomic affiliation of an organism. It is seldom recognized as an important facet of biodiversity, although its relevance is ecologically and evolutionarily crucial, given that it represents the diversity of responses organisms have evolved to deal with the environmental pressures exerted by their habitats. From the biodiversity conservation perspective it is also important in that as a result of human impact and loss of species, ecosystem functioning may depend on the conservation of the relevant functional groups, in addition to, or instead of species diversity. Some authors are of the opinion that functional traits (which define functional groups) provide a good indicator of ecosystem functioning, health, and future ecosystem trayectories under climate and land use change (Díaz and Cabido, 1997, 2001; Quetier et al., 2007). Because data on functional biodiversity is more easily obtained than alpha diversity, the study of functional traits constitutes a worthwhile avenue to be pursued in a biodiversity-rich region such as LAC. It is predictable that this facet of biodiversity is well developed, given the variety of ecosystems present in the region, and the explosive diversification of life forms.

Studies of functional diversity (and traits) in LAC are few and mostly still at the descriptive stage. For example, Mexican desert ecosystems (Miranda, 1955) include 43 readily distinguishable life forms, encompassing: cacti of several morpho-functional types (columnar sahuaros, chollas, Opuntias, Mammillarias and succulent, semi-buried cacti such as the mezcalin-bearing peyotes); shrubs with tiny or absent leaves (e.g., ocotillo and creosote bush), succulent rosette-like shrubs and treelets (e.g., *Agave* spp. and *Dasylirion* spp., respectively); arborescent palm-like plants (e.g., yuccas); and drought-resistant trees such as pinyon pines and junipers among the conifers, and bark-peeling plants such as Burseras; and a great variety of ephemeral annual plants (e.g., Dahlias). In a similar vein the more than 300 species of *Senecio*, 135 species of *Calceolaria* and 88 species of *Adesmia* in above treeline habitats in the South American Andes exhibit notable life-form diversity at the single taxon level.

In tropical rain forest ecosystems, the diversity of plant life forms is equally spectacular, including: trees in a variety of sizes with some 50 meter (or even taller) giants; massive lianas; understory shrubs; gigantic or low-stature palms; palms that operate as lianas; epiphytic trees; herbaceous climbers; herbaceous epiphytes, among which orchids, ferns and bromeliads are predominant; and the spectacular hemi-epiphytic strangler trees. Notably, the temperate rainforest of southern South America, which is dominated by angiosperm trees, shows much higher tree diversity and life-form diversity than equivalent temperate rainforests in the northern hemisphere. In these forests the contribution of climbers (lianas and vines) comes close to that in tropical rainforest in N.W. Australia (Arroyo et al., 1996). These globally scarce forests, forming a small isolated island separated by more than 1 000 km from the nearest closed-canopy forest on the South American continent, contain many neotropical woody elements shared at the generic level with upland tropical forests in the Andes and with forests in the SE of Brazil. Their functional diversity indicates that they contain a much stronger signal of past warmer climates than their northern hemisphere temperate counterparts; thus their response to global warming is of particular theoretical interest.

A spectacular example from the animal world concerns the Chiroptera, or bats, a phylogenetic lineage that has taken a variety of evolutionary routes to solve the challenge of finding and using their food resources. Within a given region, this group of animals includes functional groups, such as: frugivores (fruit-feeding, e.g., *Artibeus*), nectivores (or nectar-feeding, e.g., *Choeroniscus*), hematophagous (blood-feeding, e.g., *Desmodus*), piscivores (fish feeding), and insectovores (insect-feeding, e.g., *Lonchorrhina*). The diversity of adaptations to such a variety of feeding habits is displayed by the morphological variation in bat heads (see illustrations in Dirzo and Mendoza, 2008).

In marine ecosystems in LAC, life form and functional diversity is also outstanding, given the large number of habitats (Couto et al., 2003) as expressed in sandy beaches, rocky shores, sea grass beds, soft bottom communities and mangrove forests. In the sea, the water column and associated increases in pressure, together with the lack of light below the relatively shallow photic zone, promote a wide range of organism sizes (from bacteria and nanoplankton to whales), life forms (benthic sessile, benthic semi-sessile, pelagic) and physiological systems and functional groups (active, key-stone and sitting-waiting predators, grazers, omnivores, detritus consumers, filter feeders). Among the last there are groups adapted to resist desiccation in the intertidal conditions (i.e., littorinid snails, barnacles) ranging to those adapted to resist hundred of pounds of pressure and survive in deep lightless habitats. However, this aspect of biodiversity has not been critically analyzed in marine habitats in LAC where it could be profitably used as an indicator of marine ecosystem status.

2.2.6. Endemism

This metric, referring to the taxa in a specified geographical area that are found nowhere else on Earth, constitutes an important qualitative aspect of biodiversity and one that tends to bear weight in formulating conservation strategies given that biological entities of restricted distribution are particularly susceptible to global extinction if, for example, their habitats are destroyed. Endemism is renown to be high in LAC in general, and in South America in particular, given that centers of endemism tend to be concentrated at low latitudes in the Southern Hemisphere (where the continental masses are much more widely separated than in the North) and on islands. Endemism can be expressed at different levels: species, genera, families, orders or, even life forms (as is the case, for example, of seasonally dry tropical forests of Latin America, in which arborescent forms of the otherwise typically herbaceous climbers of the genus *Ipomoea* [known as morning glories] can be found).

At the continental level, LAC is rich in endemism for vascular plants (Figure 5), when considering both absolute number of endemic species and endemic species as a proportion of the total number of species, with the notable exception of Brazil which shows relatively low levels of plant endemism. Nevertheless, it is worth considering that there is much variation within this large country, with some areas having considerable plant endemism, such as the Cerrado. Mammals, amphibians, reptiles and birds (Figure 5) all show remarkably high levels of endemism in LAC on a per country basis, when compared to other continents, and this is evident when analyzing both the absolute and the proportional number of species. In contrast to the situation observed in the case of vascular plants, the contribution of Brazil to higher vertebrate endemism in LAC is marked, and this is consistent when considering absolute and relative numbers of species of mammals, reptiles, amphibians, and birds (Figure 5).

The mega-diverse countries of LAC, in addition to species richness, also show high absolute numbers of endemic species of plants, mammals, birds and reptiles (Figure 6). By far the highest absolute numbers of endemic species correspond to plants and, not surprisingly, there seems to be a gradient of increasing endemism as the organisms become more sessile, in the direction: plants (the most sessile) > reptiles > mammals > birds (least sessile). Notwithstanding the effects of area and predominant types of biome in each of these countries, as discussed above, it is worth noticing that Mexico, a country that is only partly tropical, ranks highest in proportional endemism of plants, reptiles, mammals and second in birds, thus highlighting that extra-tropical countries in LAC, even if not as diverse as the tropical ones, can nevertheless have high levels of endemism.

Endemism is clearly scale dependent, yet predictive theories on the distribution of endemics are limited. Here we analyze endemism in LAC on a Bylov plot (Dirzo

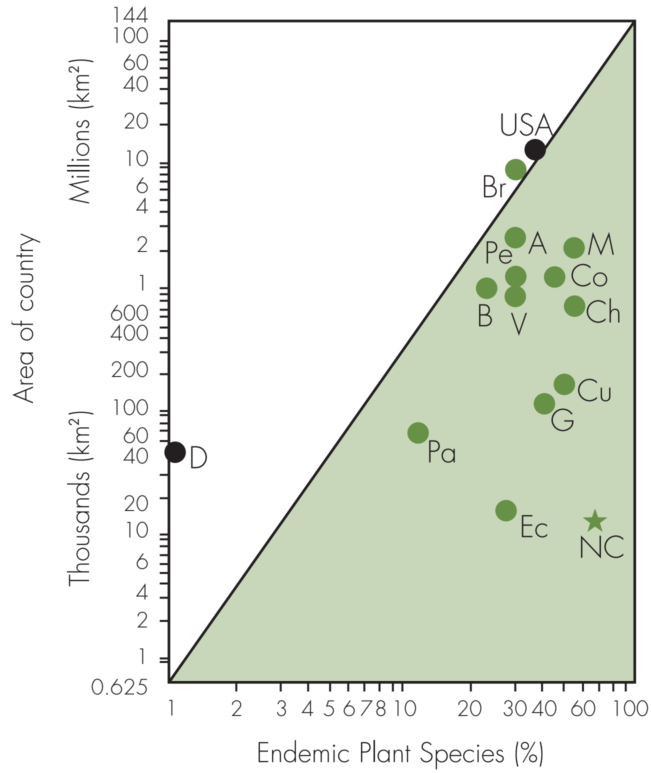


Figure 9. A Bykov plot of plant endemism (taken from Dirzo and Raven 2003) showing the relationship between percentage of endemic plant species in different countries and their corresponding area. The diagonal runs across a minimum of 1% endemic plant species and its corresponding area to the total number of plant species endemic to the Earth in the total surface land area. Latin American countries shown are: Argentina (A), Bolivia (B), Colombia (Co), Chile, Cuba (Cu), Ecuador (Ec), Guatemala (G), Mexico (M), Peru (P) and Venezuela (V). For comparison, we also show a country of depauperate endemism, Denmark (D), a country laying on the expected USA, and one the global hotspots (Myers *et al*. 2000), New Caledonia (NC). Percent endemism and their original area obtained from Myers et al. 2000). The shaded area below the diagonal in the plot shows the domain of endemism-rich regions.

and Raven, 2003) (Figure 9). Localities lying above the line (white area of the plot) will have less than average endemism for their land areas; those below the line (shaded area in the plot) will have more endemism than expected for their area. Also, as a reference, the plot shows one country, USA, which lies on the reference line, indicating that its level of endemism corresponds to that expected by its area; the plot also shows endemism-depauperate Denmark, which lies on the Y-axis, at a height of around the 50 000 km^2 tick; finally, the plot shows an extremely endemism-rich country, New Caledonia, which has ~70% endemic species in an area of just 18 000 km^2. This plot shows that 11 out the 12 LAC countries lie below the straight line, between the USA and New Caledonia, with greater than expected levels of plant endemism; some of these LAC countries, particularly Ecuador, and Cuba, an island, lie far from the reference line. The greater-than-expected endemism is particularly evident in South American countries, most of them largely tropical, as well as in Chile and Argentina, two non-tropical countries; and for Mexico, a Central American country. Consistent with what is observed in Figure 5, and discussed above, the only exceptional country is Brazil which, although extremely rich in species, has an endemic flora which places it essentially on the reference line. This kind of framework provides a template for subsequent comparisons of LAC at the sub-regional level, using more naturally defined areas, such as ecosystems. Future research on endemism in terrestrial habitats in LAC should also concentrate more on local endemics and rarity, as for example the identification of geographic areas with concentrations of endemic species distributed over smaller scales (2 500-10 000 km^2).

On account of the fewer barriers to dispersal, it is not surprising that endemism in marine habitats, particularly in the oceans, is less frequent than in terrestrial systems. Also, coastal and oceanic currents as well as upwelling, downwelling or the

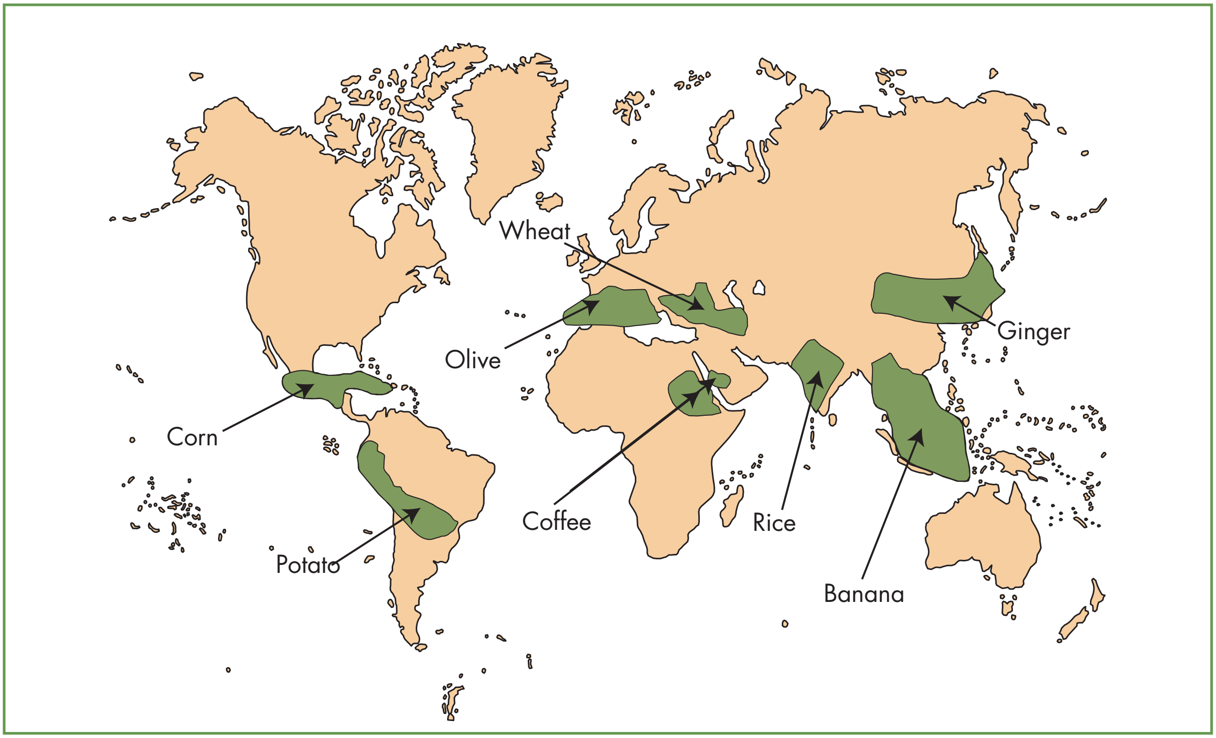


Figure 10. The centers of origin of crops and domesticated plants, and some representative examples from each of them. Two major centers are located in LAC, and two iconic examples are shown: maize from Meso America, and potato from the Andean region.

Ekman transport mechanisms, actively transport marine organisms along distances (although, retention mechanisms are also well known in the coastal zones; i.e. see Castilla and Largier, 2002). Notwithstanding, marine organisms are tightly adapted to ecological and physiological conditions (i.e, temperature, salinity, pressure, light, etc). Thus wide transportation does not necessarily translate into cosmopolitan distributions. In marine organisms endemism is more frequent on isolated islands, under retentive oceanographic conditions (Castilla and Largier, 2002) or where there are strong oceanographic barriers, such as currents, low oxygen or salinity conditions. In LAC, < 5% of the demersal and pelagic fishes off the coasts of Brazil are endemic. However, an estimated 30% of the benthic algae of the Juan Fernández Islands (Santelices, 1992), 50% of Galapagos Island fish, and 29% of coastal fish of the Juan Fernández Islands (Pequeño and Saez, 2000) are endemic.

2.2.7. Agro-biodiversity, cultural diversity and insights on genetic diversity

These aspects tend to be passed over when referring to the region´s biodiversity, yet as our brief overview on the cultural context showed, humans have interacted with LAC´s ecosystems and biodiversity for a considerable period of time, and this has precipitated domestication and semi-domestication. The amalgamation of biodiversity and cultural diversity constitute what we will refer to as biocultural diversity. Local knowledge, traditions, artistic expressions and the management of plant (and animals) collectively represent a wealth of biocultural diversity in LAC –the result of centuries of effort by local peoples to generate products of value for humans derived from profound traditional knowledge of the resources present in their surrounding environments. In this particular domain, are found a wealth of organisms with socio-economic value. In addition, agro-biodiversity is important in that it is informative, to some extent, of the Region´s genetic diversity.

A good indicator of the importance of a given geographical region from the agro-biodiversity perspective is the presence of centers of origin of agriculture and plant domestication, or Vavilovian Centers (Vavilov, 1926). Such centers are areas where plant resources are diverse and offer a significant potential for evolution under human influence, and where traditional human cultures developed a pro-

Figure 11. A collage of representative examples of crops and domesticated plants of the LAC region. Photos courtesy of Fulvio Eccardi.

found knowledge of their botanical resources with the application of such knowledge leading to the domestication of numerous crops which eventually have become some of the most important food resources for humans. Figure 10 shows the distribution of Vavilovian centers, highlighting the presence of two such centers in LAC, with corn and potato illustrated. In these prime examples, the agro-biodiversity of LAC includes a variety of domesticated and semi-domesticated species as well as many of their wild relatives (Figure 11).

Numerous compendia of agrobiodiversity have surfaced in the countries of LAC allowing reference to representative examples from the terrestrial botanical perspective. These include: maize (*Zea mays*), chile (*Capsicum annun)*, beans (*Phaseolus* spp.), calabashes, pumpkins, chayote and squashes (*Cucurbita* spp.), avocado and palta (*Persea* spp.), papaya (*Carica papaya*), vanilla (*Vanilla planifolia*), mamey (*Pouteria sapota*), cacao (*Theobroma cacao*), tomatoes (*Lycopersicum esculentum*) and tomatillos (*Physalis* spp.), jicama (*Pachyrizus erosus*), potatoes (*Solanum tuberosum*), guava (*Psidium guajaba*), sweet potato (*Ipomoea batata*), amaranth (*Amaranthus* spp.), cotton (*Gossypium hirsutum*), peanut (*Arachys hypogaea*), and yucca, cassava o manihot (*Manihot esculenta*). Presently about 98 species of manihot or cassava are recognized. All are native to the New World and are concentrated in four regions in Brazil and Central America (Nassar, 2002). Manihot does not grow wild (Rogers and Appan, 1973) and the large variation today observed (Rogers and Fleming, 1973) may be due to its having been maintained by vegetative reproduction during hundreds of years.

Less well known domesticated food plants include mango (*Bromus mango*) which was grown as a cereal by the Araucarians in southern South America, the central Andean grains, quinua or quinoa (*Chenopodium quinoa*), cañihue (*Chenopodium pallidicaule*), kiwicha (*Amaranthus caudatus*) and tarwi (*Lupinus mutabilis*), and the Andean tubers, ullucu (*Ullucus tuberosus*), oca (*Oxalis tuberosus*) and mashua (*Tropaeolum tuberosum*), to name a few.

Some domesticated species from LAC represent conglomerates of genetic variants that reach astonishing numbers, as exemplified in the case of potato, with some 1 200 distinguishable varieties for which specific uses and cosmogonies are known and practiced by indigenous communities of the Cusco region in Peru, with moreover a secondary center of diversity in south-central Chile, from whence most of the world´s domestic potatoes are now known to derive (Ríos et al., 2007) after being taken from Chiloé to the Canaries Islands.

Phenotypic and molecular data suggest that agrobiodiversity was domesticated independently in at least two different parts of LAC, as is the case of *Phaseolus vulgaris* and squash, *Cucurbita pepo* (Burger et al, 2008). Others examples were carried around by the Amerindians, with new local varieties being selected. The 'Arual' people (tuber-eating people), who lived in the northern part of the Amazon more than a thousand years ago, grew cassava and practiced agriculture (MacNeish, 1964). They were obliged to migrate in the 11th century to Central America, crossing the Caribbean Sea and settling first in the West Indies. Cassava carried by the Aruak to Mexico would be expected to have hybridized with local wild species, creating a center of diversity in this region. The history of the Aruak migration to the Bolivian Planalto and to central Brazil would explain the existence of the two centers of diversity in these regions for Cassava. The northeastern Brazilian center of diversity is believed to be a result of the Tupi-Guarani group migration (Schmidt, 1951; Nassar, 1978 a, b).

While management and domestication has typically involved short-lived, mostly herbaceous species, ongoing management and probably domestication in action are being performed and also practiced with longer-lived plants, including trees. For example, the tropical tree *Brosimum alicastrum* (for which a variety of Maya or other language names exist) is widely propagated and protected by the Mayan in Central America because the tree is used in a variety of ways; the fruits are taken as food for humans and animals; the seeds are eaten toasted and to produce caffein-free coffee; the latex is used for combating asthma and bronchites, and also as a galactogenic agent for animals and women; the foliage is also used for domestic animals and the wood is used for construction and furniture. Validation of the use of this tree stems from analysis of its chemical properties, which reveals a high content of protein (13.5%), calcium (15%), phosphorus (36%), iron (1%), vitamin A (80%); ascorbic acid (28%) and traces of amino acids such as tryptophan. Interestingly, tropical forest in the Central American region exhibits a marked, perhaps unusual dominance of this species, which very likely reflects a legacy of sustained, ancient management.

Another woody example is seen in Peach Palm (*Bactris gasipaes*), undoubtedly the most important palm of pre-Columbian America, and which came to constitute a main crop of the Amerindians over extensive areas of the humid and some areas of the dry tropics. Brazil nuts (*Bertholletia excelsa*), Açaí (*Euterpe oleraceae*) and Cupuaçu (*Theobroma grandiflorum*) have been extensively used by indigenous peoples, as well as by local communities in the Amazon as a primary food source for generations (Muñiz-Miret et al., 1996). Other tree species used are: cupuí (*Theobroma subincanum*), cajú (*Anacardium occidentale*), genipap (*Genipa americana*), papaya (*Carica papaya*), guava (*Psidium guajava*), abiú (*Pouteria caimito*), custard apple (*Annona squamosa*), biribá (*Rollinia mucosa*), pitomba (*Talisia esculenta*) Radlk.), mangaba (*Hancornia* spp. and *Parahancornia* spp.), murici (*Byrsonima* spp.), pajurá (*Couepia bracteosa*), and species of the genus *Inga*, (Fabaceae) (Miller and Nair, 2006). The large seeds of *Araucaria araucana* (piñones) constitute the main carbohydrate source of the Pehuenches in southern South America. They are still consumed extensively today by these peoples as well as commercialized in local markets. The Pehuenches also used *Araucaria* seeds and berries of *Aristotelia chilensis* to make alcoholic beverages. Some of these woody species were domesticated, while others were semi-domesticated or managed in the wild.

Among beverages, there are two important contributions. Yerba mate (*Ilex paraguariensis*) has been used for centuries by indigenous people from Paraguay, Brazil, Argentina, and Uruguay as a social and medicinal beverage. Yerba Mate has been shown to be hypocholesterolemic, hepatoprotective, a central nervous system stimulant, diuretic, and to benefit the cardiovascular system (Heck and De Mejia, 2007). Another good example is guaraná (*Paullinia cupana*) used in the Amazon region.

Beyond the constellation of domesticated and semi-domesticated plants and their varieties, many other species are managed with different degrees of intensity, ranging from cultivation or maintenance in home gardens to grafting, trimming and releasing from competition and pests in human-dominated agroscapes to direct management in the wild. In Mexico, some 7 000 native species are used for a variety of purposes, including: medicinal, ceremonial, insecticidal, psychotropic; for food, meat softener, food for bees, baits for fishing; textiles, paper, chewing gum; fuel; construction, fences, painting, staining, lacquer, waxing; cosmetics, soaps, ornamentals; hundreds of semi-cultivated plants (backyard gardens: epazote, nanche, quelites, etc.). Even in the most extreme environments, such as on the Chilean Altipano, the Aymara people, living above 4 000 m.a.s.l. use 64% of the species for some purpose in their daily lives, with 45% of the species used as forage plants (225 species studied). Vernacular names have been developed for 74% of the flora (Castro et al., 1982).

Information on domesticated animals is more limited, although it is known that several ancient cultures domesticated a variety of species such as the escuintle (a type of dog in the same Clade as the Siberian Husky and German Shepard: Vila et al., 1997) used by the Aztec, while the Inca domesticated the Andean camelids (llamas and vicuñas) (*Lama glama*, and *Vicugna pacos*) around 6 000-7 000 BP (Wheeler, 1995). Other cases of animal domestication include guinea pig (*Cavia pocellus*) in Peru, turkey (*Meleagris gallopavo mexicana*) in Mexico and the muscovy duck

(*Cairina moschata*) in Mexico south into South America. Many of these species remain in limited areas, as is the case of the Andean camelids, with only a recent trend from distribution elsewhere. Diamond (1999) explains the low number of animal domestications as a reflection of few candidates appropriate for domestication surviving extinction after the terminal Pleistocene.

Returning to genetic diversity, while cultivated and domesticated plants provide some insights into the magnitude of genetic diversity, information on genetic diversity is limited in wild species in LAC, notwithstanding the fact that the region has provided a significant number of the existing community-level plant breeding surveys, these covering several plant community types. These studies reveal that genetic self-incompatibility and dioecism are the predominant breeding systems in both tropical and temperate forests (Bawa, 1974; Ruiz and Arroyo, 1978; Riveros et al., 1996), and that outcrossing breeding systems are well represented even in extreme habitats such as the Patagonian alpine (Arroyo and Squeo, 1990). Herbaceous species generally exhibit more self-compatibility than trees (Ramírez, 1993; Arroyo and Squeo, 1990). Mostly based on allozymes at this point, studies of a wide range of temperate forest trees in southern South America reveal patterns of genetic diversity that are consistent with outcrossing (Donoso et al., 2004).

For tropical species, information on genetic diversity is more limited. Clearly, there is no reason to expect particular patterns in LAC, as genetic diversity patterns obeys general rules. As examples, a study of the phylogeography of the endangered tree species *Caryocar brasiliense*, based on variability in two classes of maternally inherited chloroplast DNA sequences, showed that eleven sequence haplotypes could be identified in a total of 160 individuals collected in 10 populations. The analysis indicated that most of the variation could be attributed to differences among populations, both for DNA sequence (87.51%) and microsatellites

(84.38%). In another example, the genetic diversity of the red mangrove (*Rhizophora mangle*), a widely distributed species in the Neotropics, including Mexico, showed that in this country there was, overall, marked genetic differentiation among populations probably influenced by genetic drift, and that populations of the Pacific coast had more genetic diversity than those of the Atlantic coast. Moraes and Derbyshire (2004) working with Brazilian Lauraceae and using 39 polymorphic allozyme loci, showed that genetic diversity among populations was fairly high and greater to what would be expected for groups of plants having a full-sib family structure. Later on Moraes et al. (2007) showed that genetic diversity was linked to phytochemical variation in the flavonoid glycosides of the leaves. Rodrigues et al. (2008), working with the Pampas deer (*Ozotoceros bezoarticus*), an endangered Neotropical cervid, and using the RAPDs, showed substantial genetic variation with all individuals possessing unique phenotypes. These and other similar studies suggest that conservation efforts directed to maintain genetic diversity need to consider not only a few (however large) natural protected areas, but a large number of sites that will maintain the constellation of populations that make up the species of interest.

In marine habitats, biocultural diversity is retained via Local Ecological Knowledge (LEK) in possession of coastal inhabitants that is passed on from generation to generation and used for adaptive management (Berkes et al., 2000). Knowledge is accumulated by coastal inhabitants on marine systems, habitats, wild species life cycles, ecology and local conditions of the sea. Domestication in the sea has been less important than in terrestrial systems (Duarte et al., 2007), except in the past 100 years where, many more aquatic species than land species have been domesticated, in association with the exponential growth of aquaculture practices (Duarte et. al, 2007). Nonetheless, different forms of basic local aquaculture or "fattening of wild organisms" used in marine artisan fisheries have emerged for large Gastropods, i.e. *Strombus* sp. in the Caribbean countries; *Concholepas concholepas* in Chile; Bivalves, i.e. mussels in different countries of LAC; Crustaceans, i.e. lobsters in Mexico; Algae, i.e. the "cochayuyo" *Durvillaea antarctica,* in Chile (Castilla and Fernández, 1998; Castilla et al., 2007).

Studies of genetic diversity in marine species in LAC are beginning to appear. As examples, reduced genetic diversity has been found in the mollusk, *Concholepas concholepas* (loco) (Cardenas, 2007) where larvae persist for long periods of time in the plankton stage (> 3 months). In this study reduced molecular biodiversity was detected using mitochondrial DNA in samples taken along more than 5 000 km of coast line, ranging from central Peru to Southern Chile. Nevertheless, new studies using microsatellites (Cardenas et al., 2007) suggest some degree of population structure along the geographical range of this species and that oceanic retentive systems (bays, fiords) may play an important role in population structuring. Quite high levels of genetic diversity are maintained in the overexploited *Chorus gigantus* in Chile (Gajardo et al., 2002). Work on the several ornamental fish collected for the aquarium trade in Brazil shows that some species have low genetic differentiation between populations (Pram and Galetti, 2005). Given the number of marine and aquatic species that are being extracted from the sea, rivers and lakes, much more research on genetic diversity is required in LAC.

2.2.8. Biodiversity hotspots

Biodiversity hotspots (Myers et al., 2000) are defined on the basis of their concentration of endemic plant species and the degree of threat to the long-term survival of natural habitats in the areas where they occur. In the original definition, for an area to qualify as a Hotspot, it must include a minimum of 1 500 endemic plant species (equivalent to 0.6% of the 250 000 described species estimated to have been named at that time), and have no more than 30% of its original habitat remaining completely intact. The hotspot concept emphasizes critical areas given their unique biotas (as exemplified by plants) and the risk of such biodiversity going globally extinct. A more colloquial version of the Hotspot concept can refer to areas of high biodiversity in general.

LAC contains a significant number of hotspots, with seven of the 25 Global Biodiversity Hotspots represented: Central America, Caribbean, Chocó/Darién/W. Ecuador, Tropical Andes, Brazilian Cerrado, Brazil's Atlantic forest and Central Chile. Many LAC scientists were responsible for obtaining the original data that defined these hotspots. The Latin American hotspots include regions in which the predominant biome is tropical forest, as well as islands or the combination thereof –tropical islands. Nevertheless, this tropical forest-endemism association is not universal. The outstanding number of hotspots in LAC reflects high concentrations of endemic taxa in Mediterranean ecosystems (e.g., Central Chile), arid lands (e.g., Mexican and South American deserts), non-tropical oceanic islands, ecological islands such as temperate-forest sierras (e.g., Sierra Madre Oriental and Occidental in Mexico), the mid-elevation cloud forests of Central and South America, and the different variants of seasonally dry forests, including tropical dry forests of Central America and south American seasonal systems (e.g., Cerrado, Chaco and the drier variants of Caatinga and savannas), already referred to earlier. In this mosaic of endemically-rich areas we find an exuberant collection of species, genera, families and functional groups of plants and animals. In conclusion, several lines of evidence underscore the importance of LAC as a region of considerable endemism, although, clearly, additional work is warranted.

It should be noted that the above delineation of hotspots in terrestrial habitats is based on vascular plants and vertebrates, and thus is somewhat biased. As noted earlier, the latitudinal decrease in vascular plant species richness in southern South America is accompanied by an inverse trend for bryophytes. The southwestern coast of South America supports more than 5% of the world's bryophytes on less than 0.01% of the land area (Rozzi et al., 2008) (Figure 8. In the long run, once we have a better understanding of all groups of organisms, many overlapping hotspots are likely to appear, diminishing the power of this concept. However, thus far, the degree of overlap is unknown.

LAC´s temperate and tropical marine ecosystems have not been analyzed under the Myers et al. (2000) Hotspot criterion, but certainly this would be a worthwhile endeavour. The Northern, Central and Southeastern Pacific marine biodiversity has several interesting, yet unique characteristics. It embraces the marine hotspot biota of the Galapagos Archipelago (invertebrates, algae, vertebrates). North of the Galapagos there are important marine biota corridors for pelagic and benthic species. South of ca. 42°S there are unique fiord and channel ecosystems representing some of the most pristine ecosystems in the world, mimicking the Alaska-Vancouver fiord ecosystems. The strong connections between southern South America and Antarctic and Australasia, determine unique cold marine biota hotspots, while the entire Caribbean would seem to be a warm marine biodiversity hotspot.

2.2.9. Frontier forests

Frontier Forests (FFs) are defined as the world´s remaining continuous intact tracts of natural forest ecosystems that are large enough to support viable populations of all biodiversity associated with the forest, including large mammals (Bryant et al., 1997). The structure and functioning of such forests must be determined by natural phenomena (e.g. fire, landslides), and not be man-made or man-induced. FFs are dominated by indigenous tree species. FFs recognize values such as conservation value, recreation value and carbon sequestering capacity as additional values over biotic richness. The FF concept thus is more integrative than the Hotspot criterion, but for the moment is restricted to a single ecosystem. FFs tend to correspond with Conservation International´s forested Wilderness Areas (Mittermeier et al., 2002).

Under the FF criteria, 22% of the world’s forests qualify as FFs, with 75% located in three large tracts covering parts of seven countries. LAC contains an outstanding 4.6 million km^2 of FF, constituting 34% of the world total. The largest LAC tracts, according to percent of world total are: Brazil (17%), Peru (4%), Venezuela (3%), Colombia (3%), Bolivia (2%), Chile and Argentina (2%). Chile and Argentina contain the largest remaining tract of temperate FF worldwide.

Using data on species richness given in Bryant et al. (1997), Figure 12 compares the area of FF per country (considering major tracts) in LAC with estimated species richness for vascular plants found in FF. While Brazil contains the most valuable FF in LAC in terms of absolute number of plant species, Colombia follows very closely. However, Colombia contains by far the richest FF in terms of species per unit area. Using the conservative global figure of 270 000 vascular plants, Colombia´s FF, found on 15.4% of the land area of those of Brazil, house populations of 13% of the world´s entire vascular flora on a mere 1.7% of the world´s land area. Although Chilean-Argentinian temperate FF has low species richness, given that a mere 3% of the world´s FF is found in the temperate zone, the former forests have exaggerated value due to the global scarcity of such forests and their value for carbon sequestration at temperate latitudes.

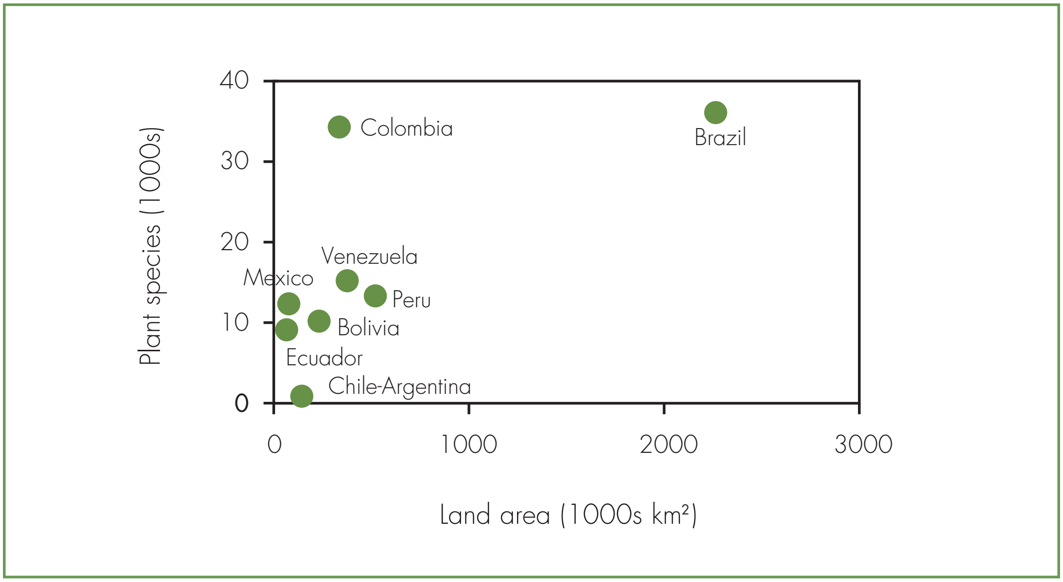


Figure 12. Comparison of land area of Latin American and Caribbean Frontier Forests with the number of species protected in each case. Original data as in Bryant et al. (1997).

2.2.10. Biotic interactions

A richness of plant-animal interactions, spanning extreme specialization to generalization, characterizes the LAC region. Such interactions, as elsewhere, are organized into complex interaction networks and are usually studied by plant reproductive biologists and community ecologists. Included are mutualisms (pollination and seed dispersal) and antagonistic interactions (herbivory and seed predation). Also, evidence for positive interactions between plant species, as opposed to competition, has been forthcoming in a number of studies performed in LAC (e.g. Cavieres et al., 2005). In general, biotic interactions are widespread in LAC on account of the prominence of tropical vegetation, and the fact that temperate forests in South America, in contrast to northern temperate latitudes, contains many tree species that are insect-pollinated and animal dispersed (Smith-Ramírez et al., 2005; Armesto and Rozzi, 1989; Aizen and Ezcurra, 1998). Even in the more extreme habitats, such as above tree line in the high Andes, insect pollination (Arroyo et al., 1982; Medan et al., 2002) and seed predation (Muñoz and Cavieres, 2006) are well represented. Such networks of interactions between species are interesting in that they represent a source of maintenance, generation and feedback of biodiversity and are reflected in a variety of ecosystem processes (e.g., plant regeneration, generation of genetic diversity) and ecosystem services (e.g., pollination and fruit production, biological control of pests). However, this facet of biodiversity, which we speculate should be well developed in LAC, has not been assessed in a comparable way to what has been described for the other metrics of biodiversity. It should be pointed out, nevertheless, that LAC has provided important sets of pollination (e.g. Arroyo et al., 1982; Morales and Aizen, 2006) seed dispersal (Galetti and Pizo, 1996) and herbivore (Lewinsohn et al., 2006) network data which have been used extensively in recent comparative and theoretical work in this area. In fact, there are probably more sets of pollination network data in LAC that for many other geographical areas.

A theoretical argument to support the above expectation is derived from the pioneer work of Jordano (1987), followed, in Latin America, by additional important theoretical and empirical contributions (e.g. Vázquez and Aizen, 2004; Lewinsohn et al., 2006; Aizen et al., 2008). Jordano (1987) analyzed patterns of connectance and strength of mutual dependence in mutualisms by comparing the fraction of possible pair-wise interactions established in plant-pollinator and plant-seed disperser systems. As the number of species in the mutualistic system increases, the absolute number of interactions also increases, but at a disproportionately higher rate than expected by the number of species of interacting plants and animals. Thus, a plot of species number (number of interacting species of plants and animals) vs. the number of interactions will have a steeper slope than that of a 1:1 relationship. A test of this expectation, using empirical data (Jordano, 1987) shows that for plant-frugivore interactions the slope of the relationship can be up to 3.5 times steeper; that is, any increase in one additional interacting species brings about 3.5 additional interactions. The corresponding figure for plant-pollinator interactions is 2.0 –a two-fold increase in interactions per each additional species. Given the high diversity of species of plants and animals (including, pollinators and dispersal agents) present in LAC, considerable richness in species interactions can be expected. Empirically, one would expect that in a plot of species richness vs. interactions richness, data points for LAC would predominantly fall to the right of the plot and increasingly far away from the 1:1 relationship.

Working with a comprehensive framework for assessing sets of species linked by interactions such as pollination, frugivory or herbivory, Lewinsohn et al. (2006) argued that differences among patterns of interactions represent outcomes of distinct evolutionary and ecological processes in highly diversified assemblages. Using flowerhead feeding insects of Asteraceae, one of the most diverse and abundant plant families in the "Campos Rupestres" of the Serra do Espinhaço complex in Minas Gerais State as a model, Lewinsohn et al. (2006) proposed that most interactions between given sets of animals and plants can be depicted as ordinations of the interacting entities that position them on a continuum of patterns. This continuum may reflect coevolutionary dynamics varying from sequential specialization to highly diversified mutualisms. A meta-analysis revealed intermediate to high correlations between plant and herbivore diversity, accounting for up to 60% of the variation in insect species richness. Tropical herbivore megadiversity can be partitioned into the following components: a] more host plant species per se, b] more arthropod species per plant species, c] higher host specificity of herbivores, d] higher species turnover (betadiversity) in the tropics than in the temperate zone (Lewinsohn and Roslin, 2008). An important conclusion of this work is that research on individual components is unlikely to resolve their relative contribution to overall herbivore diversity. Therefore, for larger-scale comparisons, the focus should be on the combined components and on herbivore beta-diversity (component d) (Lewinsohn and Roslin, 2008).

Testing the above kinds of predictions and their implications using comparable sampling efforts for a variety of plant-animal communities is an aspect that warrants further research to fully assess this aspect of biodiversity and the relative importance of LAC. Nevertheless, to for maximum rigor, ecologists needs to work with taxonomists. Finally here, work in LAC laboratories is revealing some unusual interactions. For example, although bumblebees are known to visit some red flowers in the northern hemisphere, the southern temperate rainforests of South America have revealed an outstanding number of red-flowered plants that are pollinated by the only native bumble bee of a largely paleoarctic genus that reaches the extreme south of South America (*B. dahlbomii*). The flowers of some of these species, which are red to the human eye, have been found to reflect in the blue part of the spectrum. There are probably many additional examples of unusual interactions in LAC ecosystems that are still waiting to be discovered.

2.2.11. Molecular phylogenetics and genomic perspectives

Molecular phylogenetics and phylogeography permit the detection of monophyletic clades, time of divergence, speciation rates, cryptic speciation, migration patterns, direction of character evolution and amount of phylogenetic diversity (PD), and thus are essential tools in modern biodiversity research. The past 10 years or so has witnessed an explosion of molecular phylogenetic studies involving plant and animal groups whose geographic distributions are found principally in LAC. More such studies have been undertaken in laboratories outside the region than within. Studies carried out in LAC laboratories originate mainly in Brazil, Mexico, Uruguay and Chile. Figure 13 shows the number of ISI papers involving LAC groups according to different search strings. These numbers clearly are imprecise, because not all studies that list phylogeny or phylogenetics as a key word involve new phylogenetic analyses. On the other hand, the true number of studies will be underestimated because when widely spread taxonomic groups are studied, the geographic keywords we have used in our search will not necessarily be listed.

The growing body of phylogenetic knowledge is shedding important light on the origin, diversification of LAC´s biota. For example, LAC has many monogeneric plant and animal families (e.g. Aextoxicaceae, Gomortegaceae, Ticodendraceae, Lacandoniaceae) which only phylogenetic studies can adequately resolve as relictual or recently evolved. Many new insights are being gained on the evolution of the Neotropical biota. The evolutionary origin of extant species in the Neotropics has been widely debated. One hypothesis is that Neotropical species emerged primarily during the Quaternary (the last ~2 million years), favoured by alternating glacial/interglacial climates. An alternate view proposes an older Tertiary origin linked primarily to palaeogeographical changes. A comprehensive

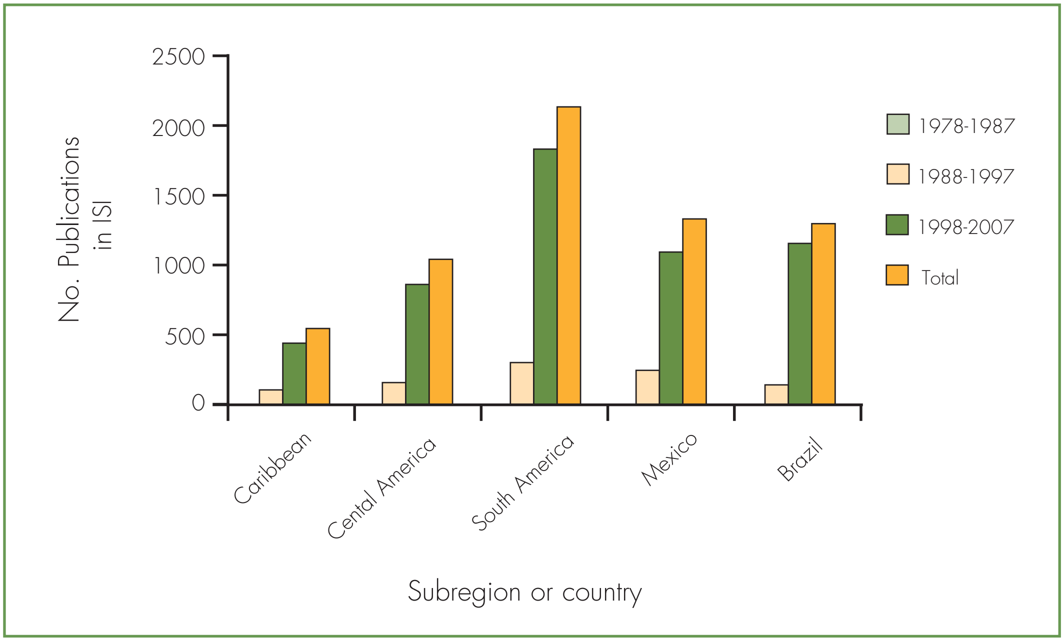


Figure 13. Estimation of tendencies in the appearance of molecular phylogenetic studies on groups of organisms distributed in Latin America and the Caribbean in ISI Web of Science for different periods time and according to different geographic keywords (as on X-Axis) plus the keyword: Phylogen.

review of the literature on DNA molecular dating across all available groups of organisms shows that both periods have been important (Rull, 2008). Around 1 400 Neotropical species whose origin has been dated have appeared in a continual fashion since the late Eocene/early Oligocene (~39 million years before present) to the Quaternary. Irrespective of when clades diverged, rapid speciation has characterized some groups. For example, the huge number of Amazonian species in the genus *Guatteria* (Annonaceae) evolved following rapid speciation in the last 6-7 million years after initial migration from Central into South America before the closing of the Isthmus of Panama, with subsequent posterior migrations back into Central America via the closed Panamanian land bridge. Similar rapid speciation has been detected in the plant genus *Inga* (Richardson et al., 2001) as of 10 Ma, with much of it occurring in the past 2 Ma as the Andes arose. Cases of cryptic species are also appearing, as in the leaflitter frog, *Eleutherodactylus ockendeni*, suggesting that our knowledge of species richness in Anurans in this area may be grossly underestimated (Elmer et al., 2007). The power of molecular phylogenetics is great for illustrating general patterns, and this area of biodiversity science should be given special support in LAC.

Phylogenetic approaches indicate great lability in species interactions, as seen in the tropical genus *Costus*, where it has been shown that hummingbird pollination evolved on several independent occasions (Kay et al., 2005), and in the largely Mediterranean-climate genus *Schizanthus* in southern South America, where generalized pollination systems associated with outcrossing have given rise to specialized systems associated with autonomous self-pollination (Pérez et al., 2006).

Vicariance and historical biogeography have long been strongholds in Latin American biogeography (cf. Morrone and Crisci, 1995; Crisci, 1998; Crisci et al., 2000; Posadas et al., 2006). While phylogenetic work has confirmed numerous cases of vicariance, as for example, on the eastern and western slopes of the Andes, many instances of long-distance dispersal into the South American Andes are now being revealed (e.g. *Saxifragella* and *Saxifraga*, Soltis et al. 2001; *Halenia*, von Hagen and Kadereit, 2003). Long distance dispersal and successful establishment has occurred in both directions between the deserts of North America (including northern Mexico), and South America (e.g. *Hoffmanseggia*, Simpson et al., 2005). Indeed, there is evidence for floristic enrichment through long distance dispersal between the rainforests of Africa and South America (Pennington and

Dick, 2004), and it has now been confirmed that long-distance dispersal underpins a number of current disjunctions between the fragments of Gondwanaland (San Martin et al., 2007). All these findings suggest that although LAC was isolated from other major continental areas for a long period of time, its biota continues to be enriched with new lineages. Morrone (2007) recommends greater inclusion of an evolutionary component in biogeography research in Latin America. Phylogenetic work in LAC is also questioning traditional dogma that biodiversity in low elevation areas is always older than in high elevation areas in the Andes (e.g., Hershkovitz et al., 2006).

Phylogenetic work is pointing to unexpectedly high rates of speciation in high elevation ecosystems in the Andes, as indicated by recent work in large genera such as *Lupinus*, *Chaetanthera* and *Astragalus* (Hershkovitz et al., 2006; Hughs and Eastwood, 2006; Sherson et al., 2008). Speciation rates in *Lupinus* in the Andes are among the highest globally, islands, included. Rapid morphological evolution is evident in high elevation taxa to the extent that many genera are turning out to be "morphological variants" of other genera, as seen in the case of the small endemic Patagonian genus, *Hamadryas*, which has recently been shown to belong in the *Ranunculus* grade (Hoot et al., 2008). At the same time, phylogenetic studies can help elucidate the age of tectonic events, such as the Andean uplift (c.f. Hershkovitz et al., 2006; Soejima et al., 2008).

One theoretical area of research where phylogenetic knowledge from LAC could be critical concerns possible differences in speciation rates between tropical and temperate organisms. It has been claimed that speciation rates in plants can be higher in the tropics (Wright et al., 2006). However, a recent study (Weir and Schluter, 2007) for birds and mammals suggests that speciation rates and extinction rates are higher at temperate latitudes. As higher speciation rates could contribute to higher species richness at tropical latitudes, it is essential to further investigate the issue of speciation (and extinction) rates according to latitude, and of course, many plant and animal groups in LAC are well set up for this, given their extended latitudinal distributions.

Phylogenetic knowledge is also important for making optimal conservation choices in LAC. Because of the concentration of species in tropical latitudes in LAC, as already mentioned, the conservation needs at temperate latitudes in LAC tends to receive less attention, despite the often high ecosystem service value of temperate ecosystems. The possibility that temperate and tropical latitudes do not differ markedly in terms of their phylogenetic diversity needs to be tested and for this, molecular phylogenetics is an essential tool. Phylogenetics and phylogeography can also help elucidate questions on Pleistocene refugia, and rates of expansion after the LGM (c.f. Lessa et al., 2003), thus providing important information on residual genetic diversity, and clues about how organisms will respond to climate change.

The era of genome sequencing opens the door for greatly expanding the scope of studies on biodiversity by ecologists and taxonomists and LAC should be there. The genomes of several species of LAC mammals have been sequenced or are about to be sequenced as part of the *Multiple Mammalian Genomes for Comparative Annotation* (an NHGRI project: genome.gov/10002154). Among these are found the nine-banded armadillo (*Dasypus novemcinctus*), guinea pig (*Cavia porcellus*), and the gray short-tailed possum *Monodelphus domestica* (work completed); alpaca (*Vicugna pacos*) and the two-toed sloth *(Choloepus hoffmanni*) (work underway); and the squirrel monkey (*Saimiri* sp.) (yet to be started). *Monodelphus domestica* is the first monotherial mammal worldwide to be sequenced (Mikkelsen et al., 2007). Some *Peromyscus* species being sequenced reach Mexico.

For invertebrates, sequencing of the genome of *Rhodnius prolixus*, the main vector of Chagas disease and of *Biomphalaria glabrata*, the main vector of the tropical disease, Schistosomiasis, is underway; some *Drosophila* species being sequenced are found in LAC. Three bacteria that affect citrus and other crops throughout the Americas have now been sequenced (*Xylella fastidiosa, Xanthomanas axonopodis, X. campestris*) (Simpson et al., 2000; da Silva et al., 2002).

No domesticated plant in LAC has been sequenced at this stage. However, recently a consortium lead by New Zealand and European institutions has been set up with the aim of sequencing *Solanum tuberosum* (potato).

Barcoding (fingerprinting) of individual species based on genome sequences, holds enormous promise for biodiversity research in biodiverse regions like LAC. The Consortium for the Barcode of Life (CBOL) has set up a target to barcode 8 000 plant species from Costa Rica (Marshall, 2005), which will be the third of three main projects of the Consortium globally. Barcoding trials have been undertaken in other groups, as for example Neotropical bats in Guyana (Clare et al., 2007) with some success. Needless to say, when used by the ecologist in field surveys, proper use of barcoding will require that a researcher is able to distinguish between closely related species in the field.

All genome sequencing projects involving LAC species have/are being undertaken by large multinational teams, with the exception of the simpler bacterial genomes which were untangled in Brazil. This emphasizes the importance of developing networking capacity in the region so as to be part of cutting edge developments in these areas.

2.2.12. Bioprospection

Despite the recently introduced concept of Combinatorial Chemistry of organic molecules achieved with the development of modern automatic synthetic methods, LAC's native biota still remains as an outstanding source for new bioactive compounds in drug discovery for pharmaceutical, cosmetic and pest control industries, as well as new items for food industries. Some progress towards making bioprospection acceptable and workable has been made in Panamá (Kursar et al., 2007).

The global demand to preserve the biodiversity in developing countries has been widely cited as a mean to promote economic development through incentives for sustainable uses of native genetic resources. In order to discover new products it is certainly necessary to evaluate large amounts of extracts or candidate compounds in preliminary biological or biochemical assays that are predictive of a corresponding and specific activity in the target organism. The probability of finding positive hits of bioactive compounds depends on the number of samples screened, the diversity of samples and the diversity of assays.

In order to establish a competitive bioprospecting program, in LAC and screen the many thousands of samples, it will be necessary to adapt local expertise to the new needs. It is true that such a network will not be able to compete with developed countries in the search for new products, especially those related to "developed countries problems/diseases". Nevertheless, we can benefit from the experience of LAC's research groups to create similar strategies to solve regional problems, especially to combat orphan diseases like Leishmaniasis, Chagas, Malaria, Dengue and other tropical diseases. In addition, the chemical diversity of species from LAC may also be a useful source of new potential anticancer, antioxidant, antifungal, anti-inflammatory or antibiotic compounds.

Bioprospection, including industrial useful enzymes for bioconversion, genes for molecular biological applications, new nutritional components, provide LAC with a great opportunity to benefit from the sustainable use of its rich biodiversity, transforming the potential economic value of its greatest asset into real wealth and a substantial improvement in regional living standards. Considering the diversity and richness of ethnic groups in LAC, the use of traditional knowledge to guide and help selecting bioprospection targets, ensuring a fair and equitable share of the benefits as established by the Convention of Biological Diversity, gives the region a large advantage to effectively benefit from bioprospection, when compared to any other region of the world.

2.2.13. Ecosystem services

Ecosystem services can be defined as *those natural functions of an ecosystem that have added value for human beings*. The concept of ecosystem services can be seen as a sociological notion that provides a useful bridge for transdisciplinary research between the biological and social sciences and is appropriate for reaching the Millennium Development Goals.

Ecosystem services include provisioning, regulating, cultural, and supporting services and such services may be direct or indirect. Direct benefits range from tangible products used by man, to ecological processes that humans knowingly or unwittingly take advantage of. Included here are the provisioning of a variety of foodstuffs, medicinal plants, fiber, fodder, compounds of pharmaceutical value, the supply of pollinator services by native pollinators to agricultural crops, the regulation of water flow used in human consumption and agriculture and recreational opportunities. Indirect benefits include carbon sequestration and its benefits in terms of regulating climate, prevention of soil erosion and landslides, the improvement of air quality, detoxification of wastes, and the maintenance of biodiversity per se, among others. Services such as carbon sequestering have already been alluded to in an early section.

As to where we are in LAC regarding research on ecosystem services, given the importance of indigenous traditions in LAC, not surprisingly, a huge body of research on medicinal, food and fiber plants found in natural ecosystems already exists in Latin America under the guise of economic botany and genetic resources. This information, however, is often found in the grey literature or local scientific journals that are often difficult to access, although electronic publication of many LAC journals has helped considerably. Likewise, national searches for compounds with pharmaceutical value are ongoing in some LAC countries (cf. Kursat et al., 2007) and should be further promoted.

The impact of land use change on the supply of pollinator services to agricultural crops has recently become a worldwide concern, leading to some of the first research on this ecosystem service in LAC. A number of studies (de Marco and Coelho, 2004; Chacoff and Aizen, 2006; Brosi et al., 2007, 2008) have demonstrated that proximity to remnants of natural vegetation increases native pollination service/production levels in crops such as grapefruit and coffee. The colonization of upland habitats in LAC has left many small forest fragments still intact, such that this particular ecosystem service is likely to be an important back-up to pollination failure by introduced honey bees and bumble bees. Such forest fragments simultaneously can supply many additional ecosystem services including the conservation of rare species that do not fall into any major protected area.

In the marine realm, Castilla (2005) analyzed Chilean small-scale shellfisheries (mainly *Concholepas concholpas*) under the ecosystem services concept. He suggested that this approach is especially appropriate when fishery legislation contemplates exclusive fishery use rights for artisan fishers and where a spatial management systems separating industrial and artisan fleets is in place. At present, a multidisciplinary team (ecologists, economists and sociologists) are evaluating ecosystems services focusing on the Chilean network of coastal reserves and marine parks and artisan fishery activities.

Recognition of the value of the constellations: natural and agroecosystems and biodiversity and cultural diversity for ecotourism, ethnotourism and agrotourism development has increased notably in LAC over the past 10 years with variation between countries. Costa Rica clearly leads, where the tourism industry (principally ecotourism) was worth US$1 200 millions a year at the turn of the century and comprises Costa Rica´s second most important source of income. The 60 000 tourists visiting the Galapagos Island generate US$100 million a year. Parks and reserves in Brazil receive 3.5 million visitors annually iadb.org/idbamerica/Spanish/JAN02S/jan02s6.html).

Temperate countries such as Chile and Argentine tend to rely heavily on their scenic heritages –and are only beginning to realize the power of combining the latter with knowledge on individual organisms and biocultural diversity. Enormous strides have been made in Cape Horn Biosphere reserve, where excellent work has been done to incorporate the knowledge of indigenous peoples into ecotourism practices. On the downside, the carbon footprint associated with air travel to such distance places is considerable.

While the above usages of ecosystem services are undoubtedly better than the wholesale and uncontrolled extraction of resources, and the blanket substitution of forests and other ecosystems, the influx of tourists in LACs national parks and reserves tends to be uncontrolled numerically. Among the principal impacts to be expected in LAC are the introduction of exotic plant species, whereby seeds and spores carried by tourists take advantage of human-mediated disturbance and trampling, and changes in the abundance of animals (and algae in coastal zones). With some notable exceptions (e.g. the Galapagos), strict controls are not in place. All this stresses the imperious need for constant monitoring and early warning systems in national parks and reserves.

The power of economic valuation of ecosystem services as a tool for promoting dialog with governments and private enterprise is beginning to be recognized in LAC following Constanza et al´s. (1997) classical paper which estimated the global economic value of ecosystem services and Balmford et al´s. (2002) later paper in which the estimated overall benefit:cost value of an effective global program for the conservation of wild habitat value, taking into account the latter's ecosystem services, is in the order of 100:1. Although there has been no specific attempt to estimate the overall value of the ecosystem services of LAC in comparison with the total world value, insights may be obtained from Constanza et al. (1997), where outstandingly high ecosystem service values were found to characterize both high and low biodiversity areas, among them the Amazon Basin, Argentine pampas, temperate forest of southern South America, parts of the Atlantic rainforest and Cerrado, and forested areas of central America. Following Constanza et al. (1997), subsequent studies have shown wide differences in economic significance of the loss of ecosystems services among biomes represented in the Del Plata Basin (Viglizzo and Frank, 2006), while use of more accurate data for the Patanal region provides a lower valuation for this region in comparison with Constanza et al´s. (1997) estimates. These examples, parenthetically, drive home one of our earlier points to the effect that biomes are far too coarse a descriptor of vegetation for detailed studies.

The value of a hectare of southern South American temperate forest in supplying water for human consumption is calculated to lie in the order of $US162 over the summer months and US$61 for the rest of the year (Nuñez et al., 2006). Finding ways to promote the conservation of this particular ecosystem service, as through economic valuation, is urgent in LAC, considering that almost 50% of the world's water is already appropriated for human consumption, without taking into account the effects of increased population in the future and climate change (Jackson et al., 2001), and that water rights in some countries are privatized, leading to possible monopolies over a scarce resource of the future. Relative to its land area, it cannot be without significance, that LAC has proportionately less water than the global average for continental water bodies.

Given the concentration of the world's mega cities along with the high proportional contribution of the urban population in LAC, the valuation of ecosystem services provided by biodiversity within urban areas constitutes a critical area of research, yet one which is only beginning to emerge. Cities are dependent on adjacent ecosystems, but can also reap sustainability benefits from street trees, lawns, parks, urban forests, wetlands, lakes, sea and streams. A recent study has shown that management of Santiago's urban greenery (natural forest remnants, street trees, shrubby and lawns) is a cost effective strategy for attaining the goal of removing particulate matter less than 10mμ from the highly polluted atmosphere (Escobedo et al., 2008). The streets and parks of Latin American cities contain a high diversity of trees and other life forms, which probably support many invertebrates and birds. We know practically nothing about the specific ecosystems services that many of these species may provide, and whether overall ecoservice value will increase by further diversifying street trees will increase. For example, if the correct flowering phenological mix is considered among tropical street trees, these could also provide food plants for tropical bees, as was seen in a planting experiment undertaken in an urban area in California (Wojcik et al., 2008). What, for example, is the tourism value of a more diverse set of trees? The development of ecosystem service research in cities in general is an exciting area of research. Organized in the right manner, it could simultaneously contribute to biodiversity conservation and education for the millions of inhabitants living in LAC´s urban areas.

It should be pointed out in passing, that some authors are of the opinion that an economy primarily based on the value of environmental services will be essential for the long-term maintenance of Amazonian forest (e.g. Fearnside, 2008), yet as Fearnside points out, institutional and international mechanisms are lacking to transform the value of the forest into an economy based on maintaining rather than destroying the forest. It should be pointed out that this last kind of obstacle is further exacerbated by a lack of solid information on carbon sequestering, water holding capacity, etc., in most ecosystems in LAC, such that while the valuation of ecosystems services is attractive as an alternative to substituting ecosystems, getting to the exact numbers required is still not always feasible in practice.

2.3. MAJOR THREATS TO LAC'S BIODIVERSITY

2.3.1. The context

In an ever-globalized world, humans in LAC and from many other corners of the world will continue to directly or indirectly shape biodiversity into the future for better or for worse, with or without consent, and at some level this is perhaps why this assessment is urgent. As the regional integration of LAC increases, the inhabitants of each country of LAC will come to exert greater effects on the biodiversity of neighboring countries, be it through the accidental introduction of exotic species, release of atmospheric greenhouse gases, or by promoting the marketing of particular commodities and hence natural resource exploitation.

In this context, the major drivers of biodiversity loss in LAC are land use change (deforestation, fragmentation, logging and burning), overexploitation, climate change, genetic impoverishment, invasive species and, especially in aquatic systems, pollution and acidification of the oceans. Some of the impacts of these drivers have already been alluded to in passing. Many of the effects of such drivers are tightly interlinked through complex feedbacks, and a complete understanding of their combined impact on biodiversity will be one of the challenges of the future. One study (Sala et al., 2000) came to the conclusion that for terrestrial ecosystems land use change will have larger impacts than climate change, which in turn will have greater impacts than biotic exchange. This general conclusion is probably true for LAC; however, detailed studies at local spatial scales are largely wanting.

The main threats to marine biodiversity in LAC are overfishing, via the acceleration of turnover of components of marine communities through fishing down food webs (Castilla, 1997; Pauly et al., 1998; Jackson et al., 2001; Myers and Worm, 2003), coastal pollution, which has already caused serious local deterioration in marine biodiversity in some countries of LAC (Castilla and Nealler, 1978), and the homogenization of marine biodiversity via the facilitation of marine invasive species, either transported accidentally by ships or intentionally for commercial reasons, (i.e. aquaculture; see Carlton and Geller, 1993; Castilla and Neill, in press).

2.3.2. Land use change

Deforestation

The world´s forests covered around 4 billon hectares in 2005. Deforestation, mainly due to the conversion of forest lands to agriculture continues, removing 13 million ha per year. South America suffered the greatest net forest reduction in 2000-2005, this being in the order of 4.3 million ha per year. Central America and the Caribbean lost a net 231 000 ha. According to FAO, rather than decreasing, the rate of deforestation in South America is increasing. The tropical forests of the Pacific coast of Central America once covered 55 million ha; less than 2% of this forest now remains. Cuba´s woodlands now cover less than 13.4% of national territory. Only 4% of the original 100 million ha of the Atlantic forest of Brazil remains as relatively pristine forest. Moreover, modern agricultural practices have converted many of the shade coffee plantations to sun coffee plantations, destroying the habitat for many wildlife species and migratory birds. Given that the Atlantic forest forms a biogeographic province on its own right (Morrone, 2001), this fact is exceedingly disturbing.

The vast Brazilian Cerrado is now disappearing at more than twice the rate as the Amazon rainforest (Machado et al., 2004). Approximate figures show that up to 75% of this biome remained fairly intact until the 1960s (Cavalcanti and Joly, 2002). Before the advent of modern techniques to correct for its acidic oligotrophic soils and high concentrations of aluminium, facilitating soy bean and eucalyptus cultivation, the major threat to Cerrado was localized in Minas Gerais state were it was converted to charcoal to be used by the steel industry. In particular, as the world focused on closed canopy forests, soy bean and plantation forestry have

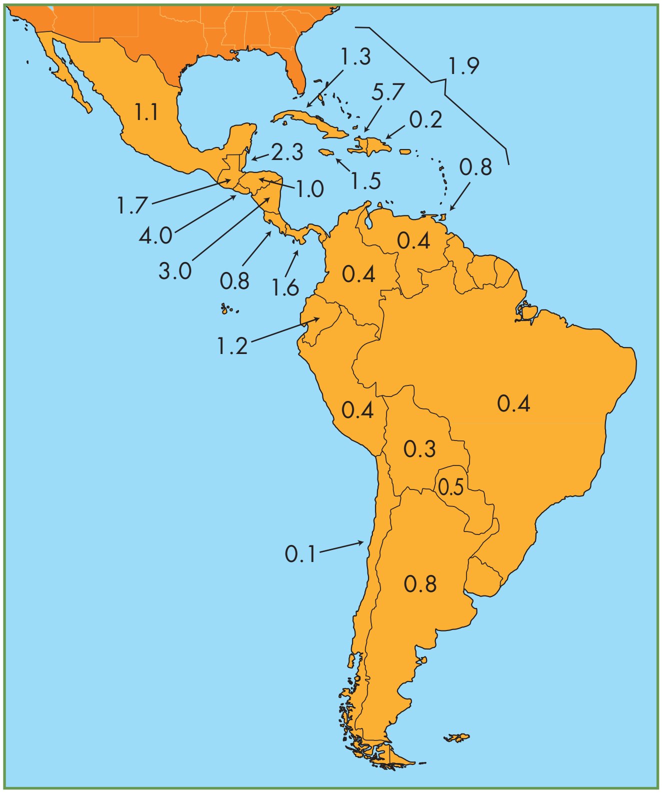


Figure 14. Deforestation rates in percent annual forest loss for countries of LAC. Data are not available for all Caribbean countries. An average for that region is also shown, based on available data for the countries shown in map. Map was constructed with data from the FAO 2008 annual report.

penetrated deeply into LACs highly endemic, yet less charismatic arid and semiarid ecosystems such as the Cerrado of Brazil and Mediterranean-type climate vegetation of central Chile. As Brazil began to use sugar-cane for ethanol production for automobile engines, huge areas of the Cerrado, one of the biologically richest areas in Brazil, were decimated. In the State of São Paulo, from 1962 to 2002, more then 90% of the Cerrado was substituted by sugar-cane, orange or eucalyptus plantations. Originally covering 14% of of the State of São Paulo (approximately 35 000 km^2), today the Cerrado covers less then 1% of the state and is fragmented into 8 500 small remnants (Kronka et al., 2005).

It is instructive for this assessment to analyze the recent trajectories of deforestation, using two complementary metrics: the annual rate of deforestation expressed as percent change, and in terms of the absolute area loss per year, using FAO statistics on a country basis for the the period 2000-2005 (Figure 14). The values range from a dramatic 5.7% per year in Haiti, to low of 0.1% in Chile. South

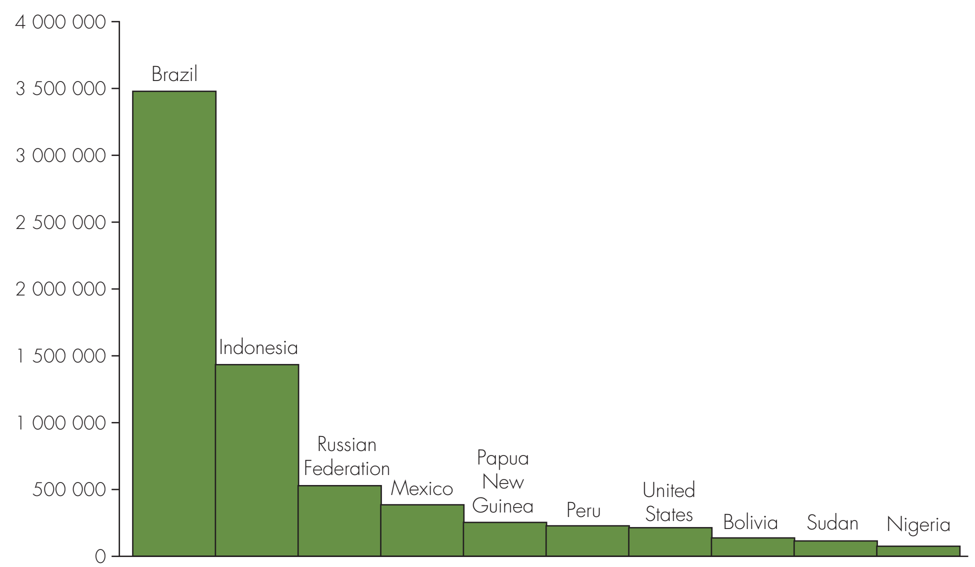


Figure 15. Countries with highest deforestation rates (ha/yr) in the world (period 2000-2005). Based on data from the FAO Global Forest Resources Assessment 2005 (FAO, 2005).

America shows relatively low values of percent annual loss, with the highest number (1.2) corresponding to Ecuador, followed by Argentina (0.8). The rest of the counties have values ≤0.5, with four of them showing an annual loss of 0.4, including Brazil, a country with a reputation of high deforestation, mainly in Amazonia. Central America is another area of high deforestation, with all but one country (Costa Rica), with annual deforestation rates ≤1.0, including Salvador, Nicaragua and Belize with 4%, 3% and 2.3% annual forest loss, respectively. The Caribbean has an average of 1.9% per country, a high number altogether, but this conceals the considerable variation among the data for the countries for which there is available information, with a range of 0.2% $year^{-1}$ (Puerto Rico), to the aforementioned extreme of 5.7% $year^{-1}$ in Haiti. The percentage values are useful in that, for example, the absolute area loss in Haiti is relatively small, but it represents significant loss for a country of that size. In contrast, the relatively low percent annual loss in Brazil represents a high absolute amount of deforestation (~3 million ha $year^{-1}$).

To further put Latin America into context, it is informative to compare the 10 countries with the highest absolute deforestation rate per year in the period 2000-2005 (Figure 15). This group of countries includes Brazil, Mexico, Peru and Bolivia, in positions first, fourth, sixth and eight, respectively. Nevertheless, deforestation in temperate LAC countries has also had its impacts, as seen in the Central Chile Biodiversity Hotspot, where Mediterranean forest is highly fragmented today (Figure 16), with plantations being dominant in some areas (Arroyo et al., 2005). This assessment comes to the conclusion that the plight of LAC´s wet and dry forests and woodlands as a result of deforestation is extremely worrying. Much more research on the impacts and mitigation of deforestation and fragmentation is needed.

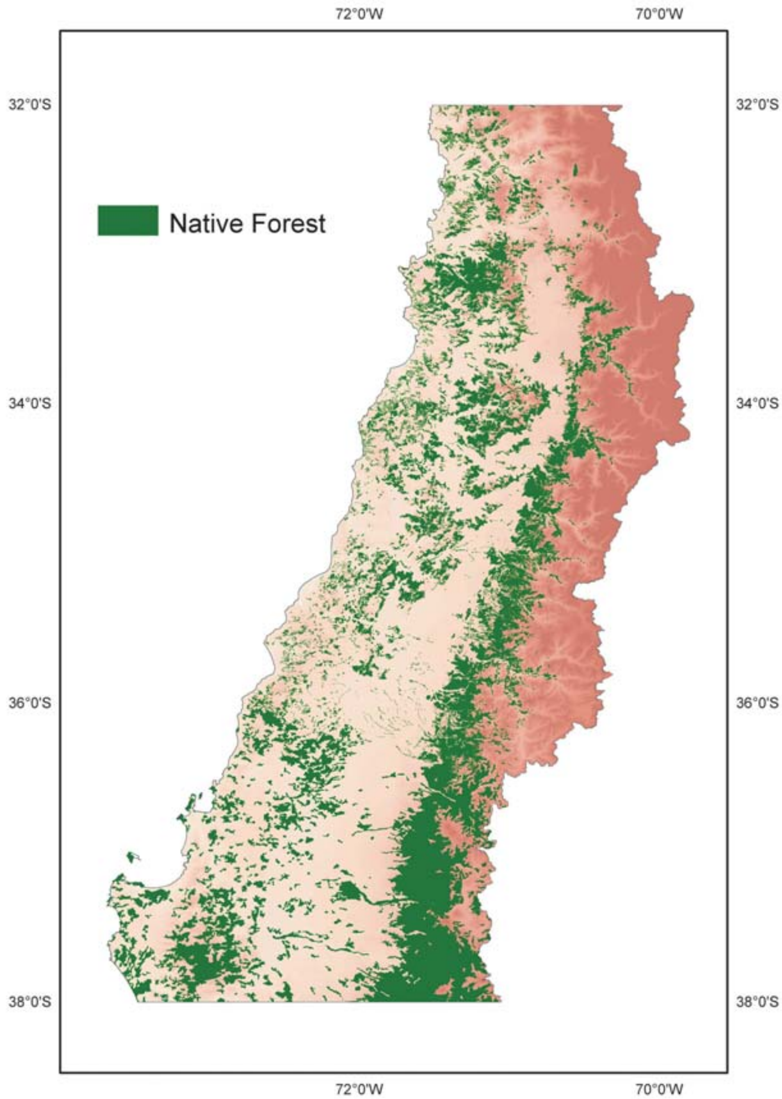


Figure 16. Habitat fragmentation in the central Chilean Biodiversity Hotspot. Reproduced with permission of Patricio Pliscoff from unpublished Masters Thesis, Facultad de Ciencias, Universidad de Chile.

Fire

Fire has been recurrent throughout LAC at multi-millennial scales at all latitudes at least since the LGM, even in the cold-wet southern temperate rainforest (Abarzúa and Moreno, 2008). A recent global analysis of charcoal remains shows that intermittent fire activity was less than at present during the deglacial period (21000-11000 BP) in temperate systems. In contrast, tropical latitudes showed greater than present levels of fire from 19000 to 17000 BP (Power et al., 2007). South America generally showed lower than present levels of fire in the Holocene from 6000 to 3000 BP. Intensification of fire in the southern temperate forest corresponds with the onset of El Ñino (Abarzúa and Moreno, 2008). Ancient fires were caused by natural events, mostly lightning, but also by volcanic activity and friction between rocks.

The extent and frequency of human-induced fire today (for clearling of land, grazing management, or by accident) far exceeds the background rate described above, although such broad baseline studies can misrepresent certain ecosystems, and not all ecosystems can be treated the same. Closed forests are the most vulnerable. As to impacts, following fire in Amazonian forests the mortality rate for tree and shrub is 36-96% (Hoffman et al., 2003). One large scale study has shown that forest stands in the Amazon basin with a history of five or more fires, average greater than 50% reduction in carbon accumulation (Zarin et al., 2005), signifying structurally impoverished forests with reduced ecosystem services.

Fire, nevertheless, is one of the major determinants of the Cerrado of Brazil, Pampas of Southern Brazil, Uruguay and Argentina and savannahs of Venezuela and Colombia (Sarmiento and Monasterio, 1971; San José and Fariñas, 1971; Coutinho, 1978; Medina and Silva, 1990; Bóo, 1997). In non-anthropic savannahs in the north of the State of Roraima in Brazil, the mean percent burned across all ecosystems for the period 1999-2000 was 38%, with fire occurring on average every 2.5 years (Imbrozio Barbosa and Fearnside, 2005). For the Pampas, fire frequency has been estimated to be 7-10 years. Pampa fires are of low intensity due to the fact that the fine material is provided by grasses which have little or no effect upon the trees (Guevara et al., 1999). Savanna species are much more fire-tolerant than forest species; in the Brazilian Cerrado, fire causes community-wide tree and shrub mortality rates of 5-19%; in a burned Bolivian dry forest mortality was 21% (Pinard et al., 1999).

There is a consensus that fire has been occurring in tropical savannas for thousands of years, shaping the landscape and selecting for adapted flora and fauna (Miranda et al., 2002). Anderson and Posey (1989) observed that the Kayapó people burned the Cerrado for its aesthetic quality, to reduce populations of snakes and scorpions, and to facilitate walking through the vegetation. The time for the burns was determined using astrological, meteorological, and ecological indicators. One temporal marker was the flowering of the pequí tree (*Caryocar brasiliense*), a key resource for the Indians. Indeed, linguistic studies have indicated a rich vocabulary of "fire" words in Cerrado tribes. This all suggests that fire has an important role to play in pre-Columbian times. Nevertheless, after humans began living in social groups, the fire frequency greatly increased over the natural background rate (Ramos-Neto and Pivello, 2000).

Although the paradigm shifts from equilibrium dynamics to a disequilibrium view of savanna functioning suggests that disturbances, such as fire may generate and sustain the coexistence of trees and grasses in savannahs through providing environmental heterogeneity, research is needed in order to determine optimal fire regimes in LAC ecosystems. On the other hand, that policy-makers are not well informed on recent advances in fire ecology has led to inadequate management policies concerning fire in preserves. Full-suppression policies come from conservative attitudes and are based on past ideas about the harmful effects of wildland fires. The policy of total fire suppression, by way of example, has proved to be inadequate in Cerrado preserves. Hot and extensive fires tend to occur when fuels accumulate, demanding huge efforts and control costs. At the other extreme, in the Cerrado and the Llanos, the intensification of fire for pasture management is causing reduction in woody plant density. To the contrary in the Chaco, exclusion of fire and grazing is leading to an increase in woody density (Bustamante et al., 2006).

In any case, without any doubt, the real threats to South American savannas are extensive cattle ranching, agricultural expansion and invasive species. Studies (Cavalcanti and Joly, 2002; Silva et al., 2006) show that from almost no impact low density cattle raising some 40 years ago, the land use of the Cerrado domain has changed to cultivated pastures with African grasses or modern mechanized agriculture, with their techniques for the rapid clearing of extensive landscapes and for the improvement of the soil fertility through liming and fertilization. Today, soybean production –the majority of which is shipped to China for animal consumption– is the major cause of the destruction of millions of hectares of savanna and seasonally dry forests in Brazil, Bolivia, Paraguay, and Argentina. In any case, the time is more than ripe for a synthesis on information on the impacts of fire in LAC ecosystems.

2.3.3. Overexploitation

In terrestrial habitats, we know that a number of native plants in LAC have been seriously harmed by overexploitation, with protection measures tending to be taken only when the situation becomes critical. Take the case of Pau Brasil/Brazilwood (*Caesalpinia echinata*, Leguminosae-Caesalpinoidae), which gave the name to Brazil. This slow growing Atlantic forest tree was first exploited by the Portuguese when they arrived in 1500. The species was heavily traded for over 500 years initially as a source of red dye and more recently as timber. Since the early 1800s, the heartwood of Pau Brasil has been used for making bows for violins, violas, cellos and basses. As a result of overexploitation, as well as habitat destruction by the ever expanding capital cities in northeastern Brazil, *Caesalpinia echinata* has become endangered. Today its known populations are small and scattered (Cardoso et al., 2005). It is classified as Endangered on the IUCN Red List since 1994 (IUCN, 2007). Fortunately, efforts are being made to preserve its germoplasm (Garcia et al., 2006). Although under Brazilian legislation, harvesting and export of the species has been suspended until establishment of scientifically-validated technical criteria to guarantee harvest sustainability and conservation of genetic material from these populations, there is ample evidence of continuing high international demand for the species, and indications of illegal trade. While there is little information on the current impact of harvest for international trade it seems likely that any such harvest might further reduce populations to the extent that the species would become eligible for inclusion in Appendix I of CITES. We Biodiversity scientist must be able to provide the evidence, one way or another.

Another plant species exploited almost to extinction in Brazil is *Euterpe edulis* (Arecaceae), locally known as "Palmito", a native palm tree of the Atlantic forest, that occurs from southern Bahia (15°S) to northern Rio Grande do Sul (30°S), mainly along the coast. *Euterpe edulis* is cut for the palm heart, a well known delicacy that is formed by its apical meristem plus young undifferentiated leaves. Being a single-stemmed palm it is necessary to kill the plant to obtain the palm heart, and its production is fully absorbed by a strong and expanding internal market. A similar fate almost befell the Chilean wine palm (*Jubaea chilensis*) of the monotypic endemic genus, which was exploited for a sweet honey product. Some 700 lts of syrup were obtained from each sacrificed individual, and used for honey or fermented as alcoholic drink. Now protected, *J. chilensis,* it is rare in the wild. Recent press publicity about this species has greatly helped its cause.

Exported Brazilian palm heart now comes almost entirely from *Euterpe oleracea,* a multi-stemmed palm tree native of the Amazon region, locally known as "Açai" from which also the fruit pulp is commercially used for energetic drinks. Although sustainable management systems for *Euterpe edulis* have been proposed (Reis et al., 1999a), the option for immediate profits prevails in the region, such that *E. edulis* has become a target of intensive and predatory harvesting. Presently, clandestine harvesting and poaching are common practices, both in public and private forests. Reduction of natural populations of *E. edulis* may have a cascade effect upon native fauna of frugivores, since it is one of the key species in their diet (Galetti and Aleixo, 1998). Genetic studies using microsatellite and allozyme markers in natural populations have demonstrated high values of outcrossing rates and gene flow for the species together with high levels of genetic variability within populations and low interpopulation genetic divergence (Reis et al., 1999b). In natural populations, the species presents a high density and a J-shaped age structure (Reis et al., 1999a, b). Currently, natural populations are intensely fragmented, and despite the high rate of outcrossing found in this species, crosses among related individuals do occur.

Other plant species that have been over-exploited in LAC are: the slow growing Andean cushion plant, *Azorella compacta*, which was exploited for fuel by the copper mining industry through the early part of the last century in Chile. Today this species is protected and one mining company has shown a willingness to finance studies to promote its restoration. Naranjilla or lulo (*Solanum quitoense* Lam.), native to Ecuador and Colombia, with important commercial value, is considered to be over-exploited. The examples given, of course, are just the tip of the iceberg. The collection of bulbs and seeds in the wild for selling inside and outside the country occurs constantly in the Mediterranean area of Chile, as does that of plants with medicinal value, although this should tend to become reduced now that the government is classifying many species under the IUCN categories.

Among animals, the Orinoco crocodile (*Crocodylus intermedius*), stands out as an overexploited species, but there are many other animals whose populations are being silently eroded. According to the Trade Environment Data Base (www.american.edu/TED/ted.htm) the illegal skin trade from Mexico represents millions of dollars annually on the black market. The United States and 114 other countries have signed the CITES treaty implementing the ban on reptile skins and furs from endangered species; the enforcement of these bans, however, is extremely difficult. Exotic birds and butterflies, animals for pets and fossils are extracted from LAC by the thousands each year in what is a lucrative business. Police confiscated more than 50 000 captured animals in one part of Brazil's Atlantic rain forest in 2005, up from 15 000 five years earlier, according to a recent report by the Brazilian National Network Against Wild Animal Trade (RENCTAS).

More than 50% of world marine fish biomass falls in the range of full-exploitation and total fish landing in the world show a pattern of descent, from a maximum of about 100 million tonnes per year reached about 10 years ago to 80 or less million tonnes per year. LAC´s has seen overexploitation as a result of an excessive fishery effort, increase of fleets, permissive governmental incentives, on occasion, in combination with natural phenomena such as El Niño, all of which have contributed to dramatic reductions in marine fisheries (e.g. anchovy and sardines for

Peru and Chile). Such over exploitation has affected both industrial as well as artisan fisheries (Castilla, 1997).

In marine systems nevertheless it is often difficult to demonstrate the effect of harvesting practices on biodiversity, as a result of lack of easy access to oceanic systems and less basic taxonomic and distribution data than in terrestrial ecosystems. It is well known that the excessive extraction of large and efficient predators (sharks, other) in oceanic systems has translated into the reduction of trophic webs in landing species. In LAC such ecosystem modification has been documented in the Humboldt Ecosystem of northern Chile. Conservation of marine commercial species is directly linked to this critical aspect of ecosystem functioning. In most instances these ecosystems effects are based on overexploitation due to industrial fleets regulated via open access fishery policies or top-down and control-command strategies (Defeo and Castilla, 2005).

2.3.4. Pollution and poor management

Effects of pollution are most evident in marine and aquatic systems. Pollution may be produced by industrial causes, or by harvesting practices themselves. Aquaculture (marine and freshwater) has increased significantly from 4.3 millions of tonnes (1979-1981) to 35.3 million tonnes (1999-2000) (Earth Trend Data Tables, Coastal and Marine Ecosystems, WRI). The predicted growth of this practice is a global production of approximately 80-90 million tonnes per year (this is approximately the present total landing tonnes per year of wild marine resources). According to the World Resource Institute (WRI) Earth Trends Data Tables for Coastal and Marine Ecosystems, marine aquaculture (salmon farming) in southern Chile is now at over 400 metric tonnes per year and second only to Norway.

Although the exploitation of southern temperate forest has slowed in the past 10 years, salmon farming has penetrated into some of the most pristine fiords in the world in southern Chile. The main problems associated with marine aquaculture in LAC are: a] the release of dissolved and particulate waste into the ecosystems (nutrient loading), b] conflict over the use of coastal spaces along the coast with the tourism industry), c] cultures of fishes, shellfishes or algae species being either accidentally or deliberately introduced into the wild, causing potentially negative effects on wild resources or ecosystems via detrimental genetic effects or interactions between strains and wild populations, d] the introduction non-native aquaculture species, with connotations regarding the spread of new diseases, parasites and other invasive species. Notably, aquaculture is the second most important vector for species introductions in marine ecosystems, following maritime transport. Salmon virus diseases, as of this year, are now rife in the northern part of the salmon zone in Chile.

Industrial pollution seems already to have affected Brazilian algae, where number of species declined in the Santos region of the State of Sao Paulo in several groups, most notably the brown and red alga, with 63% and 38% reductions in species numbers, respectively (Giulietti et al., 2005b). The copper and iron ore mining industry in Chile discharges heavy metals into coastal zones in the north of the country. Experimental work shows that copper concentrations in the range found in the field inhibits early development of the sporophytic and gametophytic stages of algae (Contreras et al., 2007). We can only surmise that cases of this last kind are far more common than reported due to observation or experimental studies throughout the region and the lack of enforcement of monitoring programs in development projects. It is imperative that LAC scientists undertake more research of the preemptive action kind, so as to avert disaster.

2.3.5. Biological invasions

Biological invasions are considered to be one of the most fast-moving manifestations of global change and a mounting threat to biodiversity (Sala et al., 2000). Invasive species can affect indigenous biodiversity by outcompeting native species through preemption of space and resources, through predation, and by introducing diseases. Plants and animals are being carried around the globe intentionally or unintentionally by humans at rates that far exceed the background rates for biotic exchange, and these rates are likely to increase as globalization proceeds. Intentional cases include the introduction of new food plants, ornamentals, game animals, pets, etc. Unintentional introductions arrive in ballast water, on imported fruit and vegetables, on the shoes and clothes of travelers, in imported wooden furniture, on exported logs, and in mud on vehicle tires, to mention a few of the main avenues of introduction. Using an example from LAC, the native flora of the Galápagos Islands gained one new plant species by natural long-distance dispersal approximately every 100 000 years over its three million year history (Porter, 1983). Humans have assisted plant introductions at the rate of 10 species per year over the last 20 years, the equivalent of 100 000 times the natural background rate (Rejmánek, 2005).

Serious invaders, once established, tend to move very quickly. Again, using an example for LAC, scientists studying the African claw frog (Lobos and Jaksic, 2005) after it had been dumped into a stream close to the international airport in Santiago in 1973, found that it has been invading at the rate of 3.1-5.5 km/year and had expanded to four political regions in Chile by 2005. Because many invasive plant species are weedy in nature, invasive species can also affect agriculture, forestry, fishing and water supplies. The control of aggressive invasive species in the USA has signified huge economic costs (Pimentel et al., 2000). We simply have no idea of the total economic costs occasioned by invasive species in LAC.

Scientists have yet to agree on a universal definition of invasion provoked by human-mediated biotic exchange (see for example Pysek et al., 2004; Valéry et al., 2008; Rejmánek, 2005). Some authors restrict invasion to alien (= non-indigenous, exotic or introduced) species, whereas others include native species with invading characteristics. Some definitions focus more on the process of interchange, whereas others focus more on impacts. Insofar as the impacts on biodiversity are concerned, the definition developed at the Sixth Conference of the Parties (COP6) of the Convention on Biological Diversity (CBD 2002), is appropriate: invasive alien species are that subset of alien species whose introduction and/or spread threaten biological diversity. This definition echoes that of the World Conservation Union (IUCN, 2000) where an alien invasive species is an alien which has become established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity. Under these definitions, alien is interpreted as introduced into another region beyond the species natural range. For practical limitations country boundaries generally define the units of comparison, although this clearly has many serious limitations.

Knowledge on invasive or potentially invasive species is highly asymmetrical between the countries of LAC in terms of: what information exists, what is readily available in each country, and research breadth. This largely reflects differences in levels of exploration of the native biota, leading to a certain neglect of, or even distain for considering exotics in those countries still struggling to complete their basic inventories. The most abundant information available in LAC concerns lists of alien species in flora and faunistic treatments. Where such lists are available, exotics in terrestrial habitats tend to be proportionately more abundant in the temperate latitudes as seen in 690 species for a total flora of around 5 000 species in Chile (Arroyo et al., 2000), versus 595 for a total flora of ca. 16 000 in Ecuador (Jørgensen and León-Yáñez, 1999) and 618 species in Mexico with a total flora of 23 000 species (Villaseñor and Espinosa-García, 2004), with an abundance of species of European origin in all cases. Such lists, where they have been analyzed for minimum residence time, indicate a continuous flow of aliens since the time of European arrival. Although not investigated, there are likely to be cases of plants that were carried around by the Amerindians. In the sea, knowledge of exotic

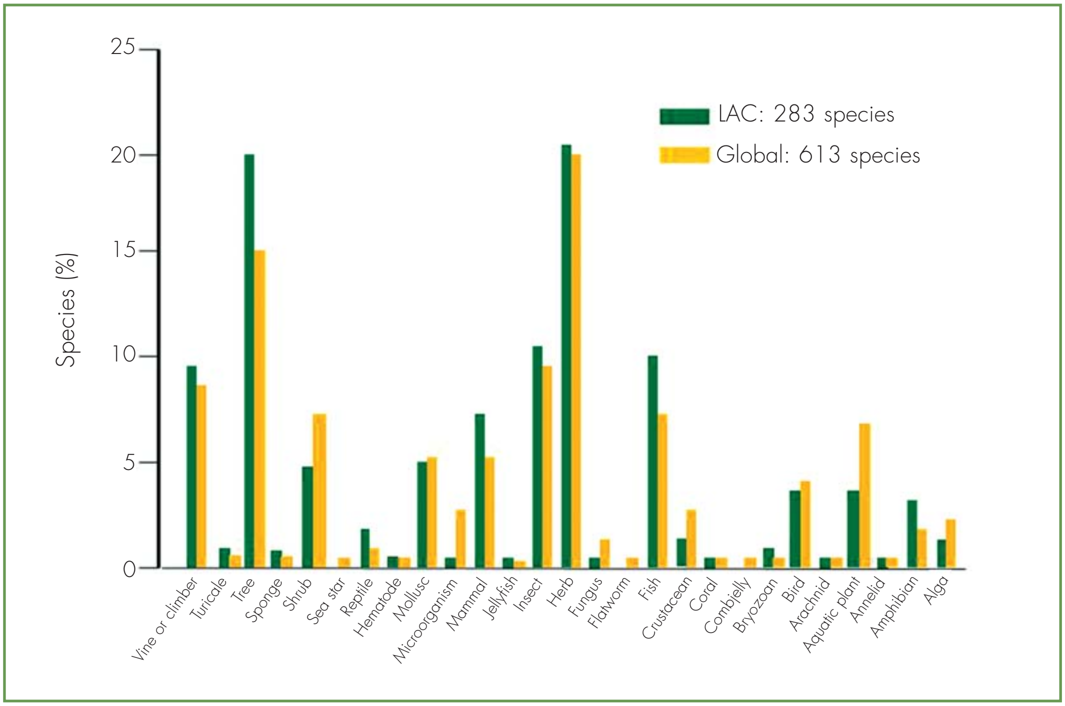


Figure 17. Species reported in the Global Invasive Species Data Base (www.issg.org/database) for Latin America and the Caribbean according to group of organisms, compared with the entire set of species in the data base for the same categories.

species on a country basis is still poor. Some 25 invasive or non-indigenous species have been identified among free living benthic marine invertebrates in Chile (Lee et al., 2008).

In order to obtain insight on general tendencies in LAC regarding invasion (as opposed to the introduction of exotics sensu lato), we have relied on information in the Global Invasive Species Data Base (www.issg.org/database/species/search.asp?st=100ss), which compiles information under a common set of standards, and requires evidence of serious impacts for inclusion of a species. We hasten to note that we are fully aware that not all highly invasive species in LAC are registered in this data base. Of the 613 strongly invading species found in this data base, 283 (46%) are registered as invasive in one or more countries/territories of LAC. The distribution of invaders (Figure 17) shows that LAC has been invaded by almost all recognized invader groups, including, plants, vertebrates, invertebrates, microorganisms and fungi. LAC territories moreover have been the recipient of 54 (=54%) of the Global Invasive Species Data Base list of 100 of the World's Worst Invaders. However, it is too early to determine whether the LAC region is invaded to a greater or lesser degree with respect to other parts of the world.

As indicated by the relative lengths of the bars in Figure 17, according to the data as it stands, the territories of LAC have been invaded more often by trees, vines and climbers, mammals, fish, amphibians, and marginally more by insects in comparison with the relative frequencies of such groups on a world scale. To the contrary, it would seem that LAC has been less invaded by shrubs, microorganisms, fungi, aquatic plants, herbaceous non- aquatic plants, fungi, algae and birds. The connotations of these tendencies, and indeed, whether they really reflect reality, given the state of knowledge in this area, are yet to be seen, but it is well known that a few aggressive woody species can cause huge impacts on biodiversity, as can insects. Currently a very high proportion of the invaders are found in 1-5 LAC territories (76%), with only a couple of species found in more than 3/4 of the countries/territories (Figure 18. Whether this means that many invaders will expand further throughout LAC in the future remains to be seen. The geographic distribution of the worst 100 invaders found in LAC (Figure 18) indeed suggests just that and should be cause for concern, as well as evidence that the development of early warning systems are fundamental. The median number of countries/territories occupied in LAC for this last set of invaders is five, in comparison with two for the entire set of invaders.

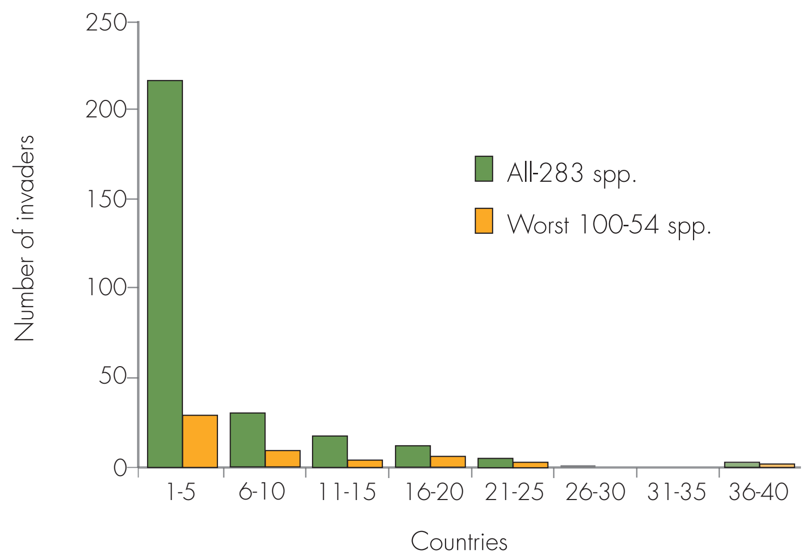


Figure 18. Degree of penetration of invaders in Latin American and the Caribbean measured by the number of countries/territories occupied for all invaders (reported in the Global Invasive Species Data Base, www.issg.org/database) comparing the full set of invaders with the World´s 100 worst invaders.

Contrary to the tendency seen in native biodiversity, it seems that size of territory is not a good predictor of the number of invaders in LAC (Figure 19). The generally larger continental territories often have received numbers of invaders similar to smaller island territories. The lack of relationship between area and number of invaders is not surprising given that biotic exchange promoted intentionally or unintentionally by humans has little to do with the size of a country. However, with just as many invaders as in the larger countries of LAC, the smaller island nations are probably at greater risk from the impacts of invasives.

Needless to say, simple percentage data on invasive species, while useful for

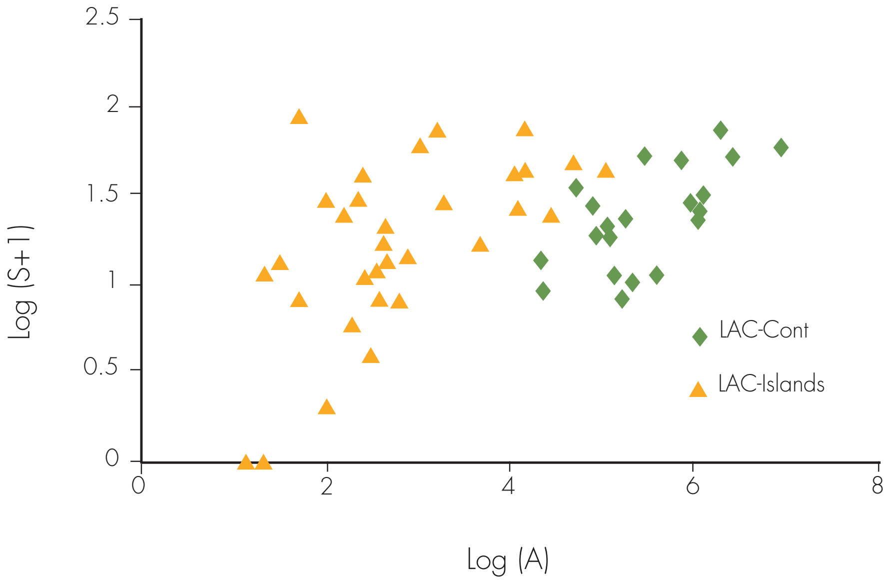


Figure 19. Number of invasive species in relation to land area for insular versus continental countries/ territories of Latin America and the Caribbean. Original data from the Global Invasive Species Data Base www.issg.org/database.

detecting global patterns, can be misleading with regard to the real impacts of invasive species, stressing again, the need for more detailed studies. A case in point concerns the exotic vertebrates of Chile, which constitute a mere 3.9% of vertebrates in the country. Yet the single European rabbit has impacted a large part of the country. Goats have decimated large areas of the unique vegetation of the Juan Fernández Islands and encouraged establishment of a multitude of exotic plant species. In the remote Cape Horn region, the 12 species of exotic vertebrates and Three species of exotic fish found there constitute more than 50% of the species in these groups (Anderson et al., 2006). In Chilean Tierra del Fuego, one of LAC´s most damaging invaders, the Canadian beaver (*Castor canadensis*), in the absence of natural predators, has increased from an initial 25 pairs introduced into Argentina in 1946 to cover 70 000 km^2, at densities of 5-6 colonies/km along river edges (Lizarralde et al., 2004), and causing serious flooding and the conversion of huge amounts of forested land to *Sphagnum* bogs. How to solve this major environmental disaster has only recently been seriously considered by Chilean and Argentine authorities –more than half a century later. In the Cape Horn Archipelago, *Mustela vison* (American Mink) was reported to occur in densities of 0.79-1.32 individuals per km on the coast of Navarino Island in 2006, yet had gone practically unnoticed since its introduction in the early 1940s (Anderson et al., 2006), thanks to the dearth of scientists in the area. These last examples underscore the need for abundance data on invasive species, early warning systems and the need for more field-oriented biologists to do the work.

As more attention is focused on alien species in LAC, we predict the number of exotic species considered to be strongly invasive will increase exponentially, and there will be hundreds of new exotic reports. We predict that exchange of terrestrial species from east to west in South America will be especially problematical, on the account of subtropical species being transported across the Andes into irrigated agricultural areas in warm mediterranean and desert areas. As a clue to what can be expected, the marine invasive species (MIS) initiative for the Wider Caribbean region has recently detected 118 marine alien species (López and Krauss, 2006), although the degree of damage these organisms cause is still not clear. A recent global survey of algal invasions published by Williams and Smith (2007) increased the number of known invasive algae by 117 species, several being from LAC. However, again, the degree of damage caused by these organisms is still not clear. The South African grass *Eragrostis plana* is said to now cover some 10% of the southern Brazilian grasslands (Ziller, 2006), yet this species is still not in the Global Invasive Species data base. There are now indications that *Pinus radiata*, one of two principal plantation forestry trees in Chile, is capable of invading adjacent farm land (Bustamante and Simonetti, 2005).

For insects, palaeoarctic *Bombus terrestris*, liberated as a pollinator of tomatoes on the Chilean coast in 1997, can be found today in abundance in the central Valley, has been sited in the Andes at 3 400 m.a.s.l., and has already crossed the Andes into Argentina (Montalve et al., 2008). The impact of this species and of another introduced bumble bee, *Bombus ruderatus,* on native biodiversity is still to be measured. Stink bugs from Ethiopia have turned up recently in Brazil (Panizzi, 2002), to name another example. As commercial interchange between the countries of LAC increases, serious pests are likely to turn up in many countries. As an example, a woody boring *Xylocopa* species was recently caught on a university campus in Chile by a graduate student. A couple of months later the bee was reported to be destroying the wood of living native trees.

The lion fish, *Pterois volitans*, native from the western Pacific and Oceania, had been reported in the USA, Bermuda and Puerto Rico since the year 2000. It was probably liberated accidentally and/or voluntarily by an aquarium owner (Chevalier et al., 2008), and has begun to invade the Caribbean, consuming many other marine organisms. Its high dissemination capacity and reproductive rate make it a species that will be very difficult to eliminate and to control, and a threat for the ecology of coral reefs. Recently, the fresh water fish, *Claria*, was introduced as a food item, and is now considered a potential danger to Cuba´s highly endemic icthiofauna.

The increasing number of tourists (and boats) visiting Antarctica, coupled with climate warming, is of special concern insofar as invasive species are concerned. For the 2006-2007 tourist seasons the International Association of Antarctica Tour Operators expects at least 28 000 visitors. Reportedly, each season Antarctica sees as many as 10 000 scientists, providing additional invasion risk. On lands, three angiosperms species currently inhabit Antarctica (*Deschampsia antarctica*, *Colobanthus quitensis* and *Poa annua*). The last is considered to have been introduced on King George Island around 1985 as a result of human activity in the area. Northern Atlantic spider crabs have been detected near the Antarctic Peninsula (http://news.nationalgeographic.com/news/2006/07/060706-antarctica_2.html). Scientists, from the Instituto Antártico Chileno, have discovered brucella antibodies in fur seals and one Weddell seal. Chile and Argentina have formal claims to territory on Antarctica, and in our view have special responsibilities to extend the defense of their claimed territories to include protection of the environment.

Much needed ecological research on invasions is beginning to emerge in Latin America. Studies have focused on: a] detecting the drivers of the spread of alien species as in central Chile, where roads were found to be important (Arroyo et al., 2000) and in *Pinus halapensis* in an Argentinian nature reserve in the Pampas, where fire provoked the spread of this planted species (Zalba et al., 2008), b] the impacts of invasive species on ecological processes and ecosystem structure (Aizen et al., 2008; Muñoz and Cavieres, 2008), c] and the impact of global warming and ENSO on invasive versus native species through experimental approaches (Cavieres et al., 2007; Gutiérrez et al., 2007). All of these last kinds of studies are fundamental for understanding the long-term impacts of invasives and their feed backs with climate and land use change, but perhaps what is most lacking is a series of specific hypotheses for LAC, clearly defined targets, and the recognition that research on fast moving invasive species requires collaboration and data sharing between scientists in different countries of the region.

Finally, it should be remembered that many serious invaders in other regions of the world have originated in LAC, pointing out that research is also needed on the invasion ecology of native species. Examples are the *Linepithema humile* (Argentine ant), *Mikania micrantha*(shrub), *Pomacea canaliculata* (mollusk), and *Eichhornia crassipes* (aquatic plant).

2.3.6. Climate change

Instrumental records show that LAC region has been warming through the 20th century. As in the rest of the world, the average temperature increased gradually from early 1900s except a somewhat cooler period in the 1960s and 1970s. In the 1980s, temperature again started to increase and has continued to increase until today, with the last ten years as the warmest period (UNEP/GRID, 2005a). According to the 2007 IPCC report, temperature increased by less than one degree in LAC over the last century. Also, there are regional differences, with more warming at the higher latitudes. Sea level rise, an important indicator of climate change, in combination with hurricane landfalls, presents one of the greatest climate-related hazards in tropical Latin America. The 1998 and 2004 hurricane seasons in the Atlantic probably exceeded previous records of hurricane intensity, damage and loss of life. However, the complex nature of hurricane formation creates high uncertainty in the future dynamics of these devastating natural events (UNEP/GRID 2005b). East of the Andes in southern South America mean annual precipitation increased by 35% in the past half-century. In Central America changes in general circulation are expected to result in less water availability. Further increases are projected with CO_2 doubling, but the models are too coarse to give reliable predictions at a local level. It must be recognized that there are still many uncertainties associated with the available climate models, although hopefully this will decrease as newer regional models become available.

Of relevance here, when forests are cleared for conversion to agriculture or pasture, a large proportion of the aboveground biomass may be burned, releasing most of its carbon rapidly into the atmosphere. Worldwide changes in land use (burning of forests, selective logging, clearing for pastures) have led to an estimated net emission of CO_2 of 121 Gt C from 1850 to 1990 (Houghton et al., 2001). Of the major categories of land-use change, the clearing of forests for use as cropland accounted for the largest fraction of CO_2 emissions from net land-use change; emissions from conversion to pastures, harvest, and shifting cultivation were lower. Most of the carbon emission in the 1980s was from tropical regions. Because of its size, the greatest extent of deforestation is in Brazil, but, as indicated previously, the deforestation rates are higher in Mexico and Argentina. Data available on CO_2 emissions for the Brazilian Amazon give estimates in the range of 1.7 ± 0.8 Gt C $year^{-1}$ to 2.4 Gt C $year^{-1}$ (Watson et al., 2000). According to projections by Shukla et al. (1990), if tropical forests in LAC were replaced by degraded pastures, there would be significant increases in surface temperature and decreases in evapotranspiration and precipitation in the Amazon basin. Furthermore, increases in the length of the dry season would make reestablishment of forests difficult. According to the IPCC report, a considerable proportion of the precipitation over the Amazon basin originates from evapotranspiration, which could be reduced by continued and large-scale deforestation.

Over all climate change is expected to impact LAC´s biodiversity both directly, through changes in temperature and precipitation affecting the availability of a species habitat, and indirectly through increasing the frequency of disturbances such as fires, hurricanes and storms, by providing opportunities for previously non harmful exotic species to increase their reproductive output and population sizes and out compete native species, and by hastening phenology. In Europe, Lenoir et al. (2008) documented an upward shift in the optimal habit for plants at the rate of 29 m per decade by comparing vegetation data from different time periods. Tree species in North America, in a favorable full dispersal scenario are expected to shift 700 km northward in the next 100 years, with a 12% decrease in range size (McKenney et al., 2007). Thomas et al. (2004) came to the conclusion that between 15-37% of the species could become extinct as a result of global warming (using a mid-range climatic scenario). Based on these kinds of patterns, species in LAC are expected to migrate southward in South America, northward in Central America, and upward in elevation across the entire region, notwithstanding environmental filtering due to changes in precipitation.

With respect to migration, a number of predictions can be made for LAC. Poleward migration should be easier in the northern extreme than in the southern part of LAC, as a result of the fact that the amount of land increases with an increase in latitude north of the tropics, while in the South America south of the equator, the opposite is true. Nevertheless, the Central America peninsula could be an important bottleneck for the migration of tropical forest species at lower latitudes north of the equator. On the other hand, the existence of major mountain ranges in LAC favors upland migration. Species found at mid elevations are expected to survive by shifting to their desired temperature ranges. Thus the eastern slope of the Andes, one of the richest areas of terrestrial biodiversity in LAC, and central Chile, a Biodiversity Hotspot, should be in fairly favorable conditions, although extensive agricultural and plantation development in central Chile can be expected to hinder migration along altitudinal gradients, while any migration advantage going to the northern tropical Andes could be counteracted by reduction in moisture due to glacier die back (Buytaert et al., 2006; Ruiz et al., 2008). Needless to say, many species found at the upper limits in the Andes and other mountain ranges are likely to loose their habitats entirely over time. The monitoring (and modeling) of high elevation species on steep altitudinal gradients in the Andes, where moreover land use changes are usually less a confounding effect than at lower elevations, constitutes perhaps the best in LAC for determining the impact of climate change on species distributions.

A number of studies have now evaluated the impact of climate change on biodiversity in LAC using modeling approaches. At the ecosystem level the recent modeling results published by Salazar et al. (2007) gives much cause for alarm (Figure 20). Using a number of climate models, these authors showed that the Amazon rainforest would be replaced in large part by savannah from here to the end the century. At the species level, Gómez Mendoza and Arriaga (2007) looked at responses of Mexican oaks and pines to the different scenarios of climate change using the regionalized HadCM2 model. The current geographic distribution of oaks and pines is predicted to decrease 7-48% and 0.2-64%, respectively. Hubbell et al. (2008) estimated likely tree-species extinctions using neutral theory under published

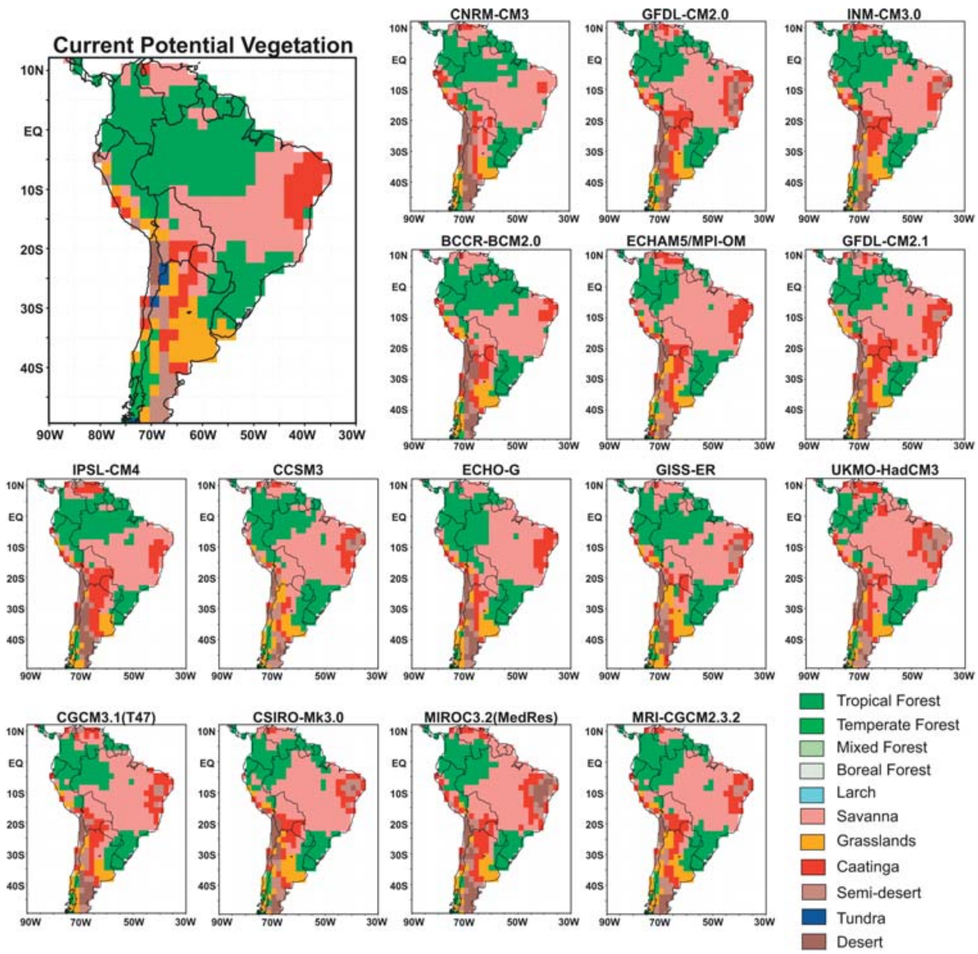


Figure 20. Projected distribution of natural biomes in South America for 2090-2099 for the A2 omissions scenario. The top left figure represents current potential biomes. From Salazar et al. (2007).

optimistic and non-optimistic Amazon scenarios for 11 210 tree species. Of these, 3 248 species with > 1 million individuals are expected to persist under both optimistic and non-optimistic scenarios. At the rare end of the abundance spectrum 5 308 species with < 10 000 individuals are expected to suffer nearly a 50% extinction rate under the non-optimistic deforestation scenario and ca. 37% loss rate even under the optimistic scenario. 20% and 33% of tree species in the Brazilian Amazon are predicted to go extinct under the optimistic and non-optimistic scenarios, respectively. If these predictions hold up, the effects of climate change in the Amazon will be enormous.

Using a niche modeling approach, Ferreira de Siqueira and Peterson (2003) studied the projected distributions of 162 Cerrado trees in Brazil under the Hadley HHGSDX%, HHGGAX50 climate models. Most of the species were projected to lose more than 50% of their potential distribution area. Colombo (2007), working with 38 species of trees of the Brazilian Atlantic Rain Forest, and using the same methodology as Ferreira de Siqueira and Peterson (2003), showed that tree species could be divided in two major groups: one group, comprising 6 species, that will be marginally affected by an increase in up to 2°C in mean average temperatures, i.e., the change in the potential distribution will be near the error margins of the methods used (± 10%); a second group, 32 species, including the palm heart (*Euterpe edulis*, Arecaceae), that will undergo significant reductions in their distributions –among the last species, two will loose more than 50% of their area of occurrence. Considering the pessimistic scenario, 50% of the 38 species studied will suffer habitat reductions of more than 50%. The estimated average reduction in habitat for the Atlantic Forest trees is lower than that reported by Ferreira de Siqueira and Peterson (2003) for Brazilian Cerrado species, and almost all species showed a displacement towards the southern area of the Atlantic Rain Forest, meeting the predictions made above. According to the IPCC models further south will not be subjected to frost and should present favorable temperatures for the group of arboreal species studied. Peterson and Shaw (2003) studying the distributions of three *Lutzomyia* sand flies, cutaneous leishmaniasis vectors in South America, also showed a displacement of the species towards southern Brazil. A niche modeling study on the native trees in Chile shows that some species will increase their ranges while others will show large decreases (F. Labra, unpublished). Here also, efforts are underway to model the effect of climate change on grape growing and the wine industry.

Some of the early distributional modeling carried out in LAC makes assumptions that may not hold up in real-life situations. In São Paulo State in southeastern Brazil, coffee plantation development was the main driver of native forest fragmentation, mainly inland semideciduous forests from 1800 to 1950. Much of the Cerrado of São Paulo was destroyed between 1970 and 2000 to make way for sugarcane for ethanol production for car engines, *Eucalyptus* –mainly for cellulose production, and orange plantations. The area, originally covering 14% of the State, has been reduced to 8 500 fragments of which less than 20 are over 1 000 ha (Kronka et al., 1998, 2005). In this highly fragmented landscape, under climate change, biodiversity conservation undoubtedly must be linked with maintenance and or restoration of biological corridors. These can be on the landscape level, reconnecting remnants of the original habitat, or at the ecoregion level, such as the Central American Biological Corridor (MBC), a transboundary system of protected areas and connecting corridors from southern Mexico to Panama (IUCN and WCPA, 2008) or the Central Corridor of Atlantic Rain Forest in Brazil. In São Paulo State, where the original vegetation has been so dramatically fragmented, the BIOTA/FAPESP Program (www.biota.org.br) has just completed the publication of a map and a book setting out priorities for biological corridors for conservation and restoration (Rodrigues et al., 2008).

In contrast with modeling, very little experimental work on global warming is being undertaken in LAC. As examples of the kind of work being done, artificial warming experiments on cushion plant species in the alpine zone of central Chile led to an increase in invasive beetle species on cushions (Cavieres et al., 2007). Arroyo et al. (1993) predicted that pollinators will respond faster to global warming than plants, given their greater mobility, possibility resulting in plant-pollinator mismatches. This aspect of climate change warrants careful study.

Many phenological studies (e.g., flowering and fruiting phenophases, time of parasitoid attacks) have been carried out in LAC ecosystems over the past 30 years or so in a variety of ecosystems (e.g. Arroyo et al., 1981; Batalhar and Mantovani, 2000; Pavón et al., 2001; Marco and Páez, 2002; Ramírez, 2002; Schöngart et al., 2002; Folgarait et al., 2003; Aizen and Vázquez, 2006). However, as far as we know, it seems that few studies were set up to be monitored a second time. In any case, phenological changes are among the first to be expected under climate warming. Phenological hastening may be sufficient to allow many long-lived species to adapt to climate change. Thus revisiting any permanent phenological sites would be well worthwhile. Likewise pulling all the original phenological data together might reveal some interesting patterns on the inverse distribution of land mass in North and South America which should affect continentality and annual temperature distribution.

With respect to the marine environment, climate change is expected to impact marine species and communities in LAC in different ways. Elevated sea water temperatures (sometimes associated with extreme El Niño events, but not always) have resulted in the loss of symbiotic zooxanthellae and coral death (Hoegh-Guldberg, 1999). Krill, a pelagic member of the crustacean suborder Euphausiacea, is of great importance in the trophic chain of the oceans. From January to April, swarms of krill (*Euphausiacea superba*) appear in the Antarctic Ocean and as result of the predominant sea currents, move northward into the Atlantic and Pacific Oceans surrounding South America. They have a large impact on fisheries along the eastern and western coasts of the subcontinent, which are of enormous economic importance. Global warming may shrink the distributions of such marine polar species leading to reductions in their abundance. The summer of 2005 saw a massive coral bleaching event in the Caribbean due to elevated sea water temperatures, which affected virtually all coral species, according to a detailed study in Barbados (Oxenford et al., 2008), with nearshore reefs being more affected than offshore reefs. 3.8% of partial colony death across all coral species had occurred by February 2006, with a large number of coral colonies still bleached after 5.5 months (Oxenford et al., 2008).

One of the most serious global climate changes in marine systems refers to biological impacts of ocean acidification that potentially may affect coral communities and a myriad of other marine calcifying organisms (mollusks, diatoms, other plankton organisms; Orr et al., 2005). Not less important are the links between changes in the climate and associated increases of diseases in the sea (Harvell et al., 2002). In the sea, sedentary coral reefs in particular, stand to be strongly affected by climate change. Finally, ultraviolet radiation in the southern cone of South America is already significant greater that in the rest of the globe and this may have important ecological and biodiversity consequences (terrestrial and marine systems), via the increase of mutations (among other related factors). To date, few of these impacts of climate change has been systematically studied in marine environments in LAC.

Complex feed backs between fish overexploitation and climate change are causing unanticipated changes in marine ecosystems as, for instance, the sudden increases of ocean surface temperatures in the Mediterranean associated with increases of medusas may be linked to the overexploitation of major top predators in this system. This leads not only to shifts in ecosystems functioning, but also impacts on economical activities such as tourism in coastal areas. Practically nothing seems to be known about these potential kinds of changes in LAC marine environments.

2.3.7. Interactions between drivers

One important gap in our knowledge in LAC concerns the consequences of interactions of drivers of biodiversity change. This area is very complex, given the rapidity with which change is occurring in LAC´s ecosystems and the often lack of compliance to the law regarding resource exploitation (e.g., fishing, hunting, logging, etc.) in isolated areas. If the aim is to reduce the impacts, it is not easy to pinpoint where the research priorities should be placed. What does seem clear is that the participation of local stakeholders and outreach are essential tools.

A typical synergism expected is an increased intensity of defaunation (the contemporary removal of animals by human impact; Dirzo and Miranda, 1991) due to over-exploitation/hunting in heavily fragmented forests of the Neotropics, the latter facilitating access to hunters onto previously inaccessible areas in the interior of tropical forest (Peres, 2001; Dirzo, 1994, 2001).

A striking case of complex synergisms at a large scale in LAC concerns the effect of pasture and soy bean expansion in Brazil (Sampaio et al., 2007). Apart from deforestation, which can be expected to lead to biodiversity loss, and per-

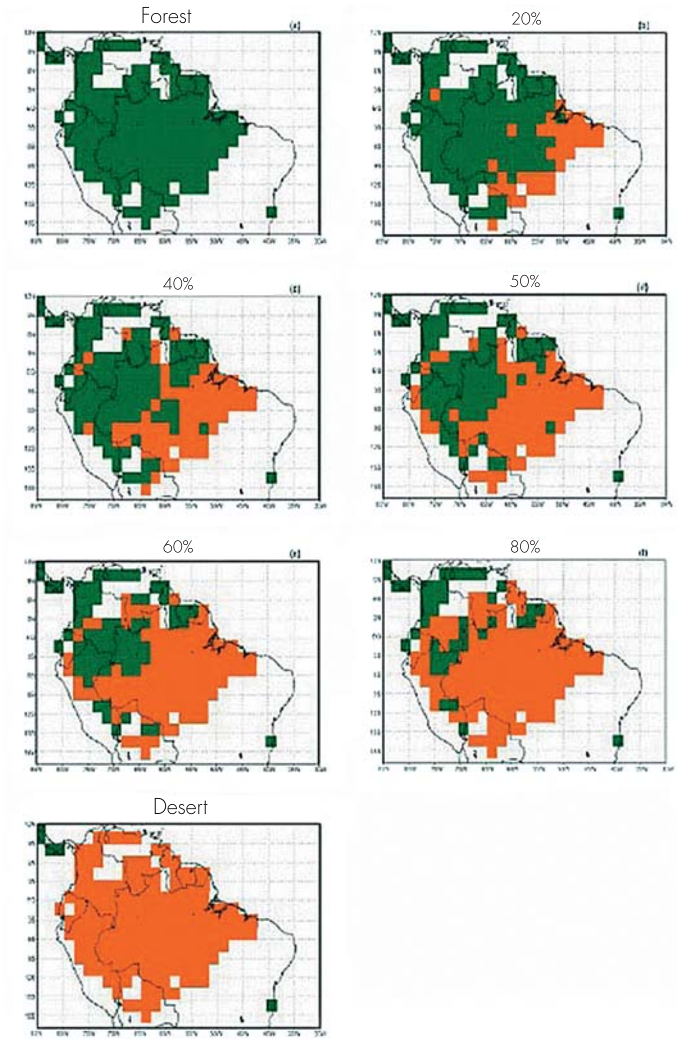


Figure 21. Deforestation scenarios for the Amazon on a ca. 2 degree lat/long grid. Control and different deforestation scenarios. Green tropical forest: orange: pasture of soybean cropland. From Sampaio et al. (2007).

haps the introduction of invasive species, increase in near surface temperature and an accelerating decrease in evapotranspiration and precipitation are expected, which should produce further impacts on biodiversity (Figure 21). Again, at a large scale, Zak et al. (2008) report that approximately 80% of undisturbed Chaco in central South America is now occupied by crops, pastures, and secondary scrub. The main proximate cause of deforestation has been agricultural expansion, soybean cultivation in particular. This appears as the result of the synergistic convergence of climatic, technological, and socioeconomic factors, supporting the hypothesis of a multiple-factor explanation for dry woody vegetation loss.

Another example from LAC, at a more local scale, concerns the sudden migration and/or death of the charismatic black necked swan (*Cygnus melancoryphus*), a tourist attraction, from the Río Cruces wetlands adjacent to the city of Valdivia in Chile in the spring of 2004. This migration coincided with the reduction in spatial extent and death of the exotic submerged macrophyte, *Egeria densa,* upon which the swan feeds. Disappearance of *Egeria densa* was attributed to increased iron content in water, precipitated in turn by aluminium-based coagulates used in the chemical treatment of liquid waste in a new nearby pulp project (Lopetegui et al., 2007). This cause has been challenged by some scientists, showing that long-term monitoring of these wetlands is desirable. In any case, activities at the pulp mill at the urging of the local community and environmentalists were stopped.

A worrying case of synergism is projected for the Antarctic. The vast majority of currently described polar biodiversity occurs on the Southern Ocean shelf but current and projected climate change is rapidly altering disturbance intensities in some regions. The Antarctic Peninsula is now amongst the fastest warming and changing regions on earth (Smale and Barnes, 2008). The intensity of ice scouring is expected to increase in the region over the next few decades as a result of decreased winter sea ice periods and increased ice loading into coastal waters. As ice fronts retreat past their respective grounding lines, sedimentation and freshening events will become relatively more important, all likely to cause significant changes in ecosystem structure, and probably a considerable loss of polar marine biodiversity, over relatively short timescales (Smale and Barnes, 2008), not to mention appropriate habitats for invasive marine species.

Less evident indirect effects are also expected when land use change causes heavy habitat fragmentation, which can lead, say, to reduced abundance of pollinators, in turn turn leading to reduced plant reproductive success and reduced genetic diversity (Aguirre and Dirzo, 2008). In this example, reduced reproduction and genetic diversity is caused indirectly by fragmentation, and directly by reduced pollinator abundance. An example of negative feedback concerns fragmentation, leading to small forest fragments, impacted by edge effects that bring about increased tree mortality at the fragment edges, with increasingly reduced fragment size and subsequent increased tree mortality in a vicious circle of events eventually leading to the collapse of the fragment (Laurance, 1998).

2.4. CONSERVATION AND THE SUSTAINABLE USE OF BIODIVERSITY

2.4.1. Conservation status

While it is not possible to determine the relative contributions of habitat loss, climate change and invasive species for the entire LAC region, concrete evidence for serious conservation problems exists. We have already alluded to some overexploited species. The IUCN Red Data books (IUCN, 2006) presently include sum totals of 3 943 animal species and 4 449 plant species from LAC countries in the Extinct,

Extinct in the Wild, Critically Endangered, Endangered and Vulnerable conservation categories. These represent over 20% and around 40% of the equivalent global sum totals across all countries of the world. The degree of overlap in species between countries is impossible to determine, such that the exact numbers here will necessarily be much smaller. However, the percentage values are unlikely to change greatly, because this confounding factor is represented among all regions. The representativity of these data varies enormously between different taxonomic groups.

Given our better knowledge on birds and larger mammals the assessment of the conservation status of these groups is comparatively more reliable. In contrast, it seems fair to say that no complete flora in LAC has been thoroughly analyzed for its conservation status at this stage (except for Ecuador, where exceptionally complete work has been undertaken), such that the existing data on plants in most countries will grossly underestimate the number of species with conservation problems. Moreover, in general, work on plants has concentrated heavily on woody species with little regard for the herbaceous flora, while work on animals has concentrated on vertebrates. The life-form bias in plants renders species-rich biomes such as deserts, alpine and mediterranean type vegetation and grazed ecosystems such as savannah and steppe grassland, grossly under-represented in the Global Red Species Lists, a trend that must be remedied. The other side of the coin concerns the fact that species assessed are often singled out as priority because of a suspected conservation problem, and thus do not necessarily represent a random sample of the conservation status of the biodiversity of an area. To overcome this bias, a few countries in LAC have implemented subregional assessments of conservation status (c.f., Squeo et al., 2008) of complete local floras and faunas, as well as the more typical focused studies. These finer-grained studies are revealing many locally endangered species and are providing a timely red light for their conservation at the global level. Nevertheless, our knowledge of extinction possibilities is poor throughout the region and requires developing faster methods for its detection (c.f. Rodríguez et al., 2007). Unfortunately, such subregional level assessments are being carried out independently in different countries, with scarce communication of results across borders.

Aside from the extinct species, the relatively low numbers of threatened species in all categories of risk, which likely reflects more ignorance than a non signoificant problem, offer a general picture of the variation across countries within LAC. The number of threatened species varies considerably but the patterns of variation are not very clear. On the one hand, the largest number (2 174), in Ecuador, may reflect, at least in part, the better quality of the data on this aspect for the country. On the other hand, the number is influenced by the richness of species of each country. With these caveats in mind, it is noticeable that, after Ecuador, the countries with the highest concentrations of threatened species are Mexico, Brazil, Colombia and Peru –all regarded as mega-diversity countries. These data underscore the need to undertake effective measures of protection of biodiversity in these hyper-diverse countries, as well as in the island countries of the Caribbean. The lowest numbers of threatened species occur in a variety of countries, including some tropical (the Guyanas), semi-tropical (Paraguay) and extra-tropical (Uruguay, Chile) ones, but again, it must be asked to what extent the data represent reality.

From a taxonomic perspective (Figure 22), the greatest contribution of threated species is found in the amphibians (32% of the total), followed by the fishes (24%), and the lowest numbers correspond to reptiles (10%), with mammals and birds in intermediate situations. These relative contributions change when considering the major sub-regions of LAC; thus, the endangerment of fishes becomes particularly prominent in the Caribbean Islands, accounting for 45% of the total, probably due

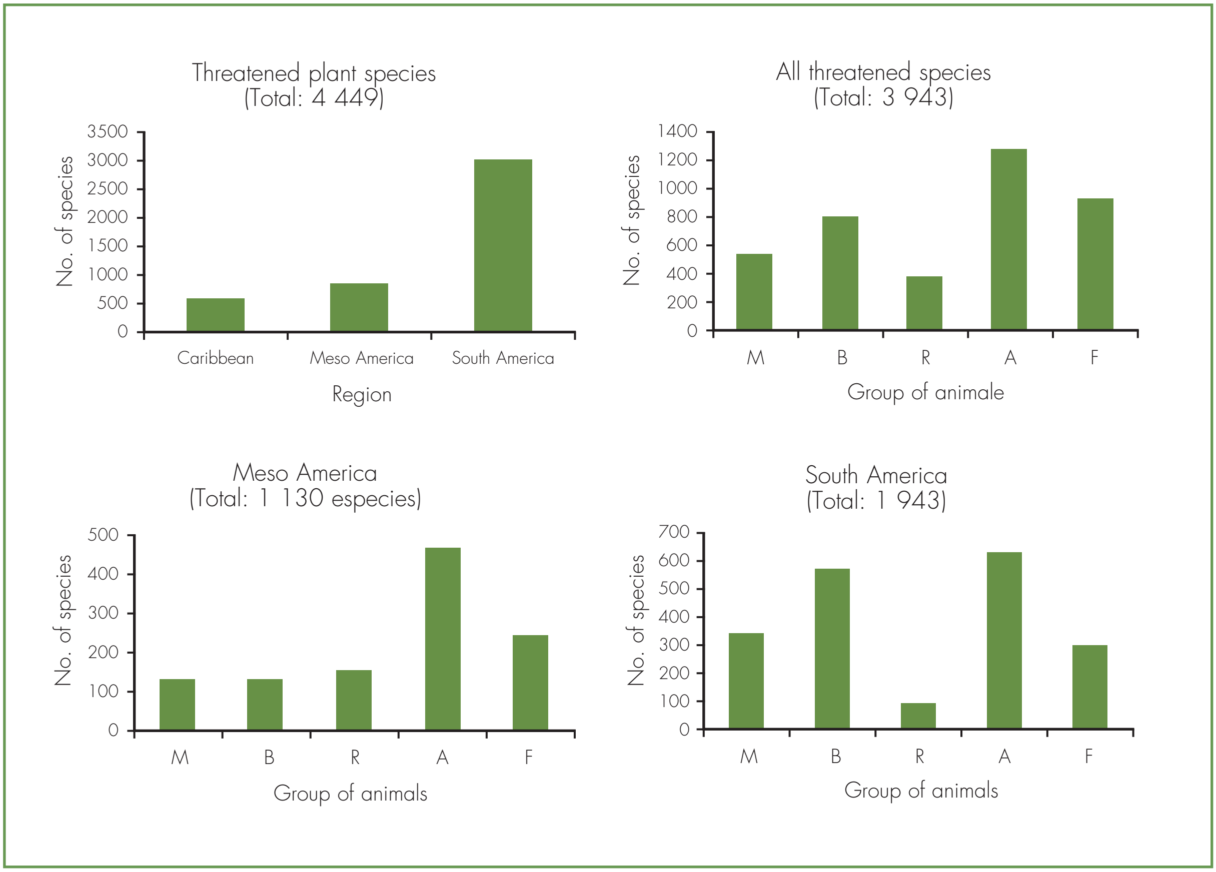


Figure 22. Histograms of threatened species in different regions of Latin America and the Caribbean for different types of organisms. Original data from 2007 IUCN Red Data Book. M =Mammals, B = Birds, R = Reptiles, A= Amphibians, F = Fishes.

to the prevalence of the marine environment in that sub-region. In Central America (Figure 22), the pattern resembles that of the overall region, with amphibians and fishes contributing the highest numbers (32% and 30%, respectively), while in South America (Figure 22), a sub-region particularly rich in birds, this group contributes to 30% of the total, only superseded by the amphibians, which account for 33% of the

1943 species endangered in that sub-region. Finally, in the case of plants, South America, with its remarkable floristic diversity, accounts for the vast majority of endangered species, with 67% catalogued as endangered in LAC by IUCN.

Finally, most of the available data and analyses focus on extinct or threatened species, while the extinction of populations is neglected. While the relevant data are not available, there can be little doubt, given the magnitude of genetic diversity and population differentiation insinuated above, that the LAC region is experiencing a widespread pulse of biological extinction at the population level in almost all ecosystems. Again, this is another crucial aspect of biodiversity conservation in LAC that warrants further research.

2.4.2. Conservation and sustainable use measures

Protected and management areas

Conservation in LAC depends heavily on state protected areas, consisting of land set aside in national parks and reserves –there being little effort to introduce conservation measures into the managed matrix. Some interesting efforts relate to indigenous peoples' practices such as participatory forestry management (Toledo et al., 2003). As of the 1960s, according to UNEP figures, globally, the amount of land and number of terrestrial and marine protected areas designated nationally has grown exponentially to around 16 million km^2, distributed in over 18 million units, to comprise 11.6% of the world´s land area. LAC followed the world trend, there being a 100% increase in land set aside for protection over the period 1990 to present with 21.2% of the land protected in some 4 700 parks and reserves. This contribution of protected land is currently the highest for all developing regions of the world and exceeds the overall percentage for the set of countries considered Developed Countries by 6.84%.

LAC´s protected areas include six of the 20 largest nationally designated protected areas in the world, four of which are found in Brazil, one in Ecuador and one in Venezuela, together protecting over half a million km^2. Included here are the Galápagos Islands which are classified as a marine reserve. Nevertheless, huge differences in the protection effort are found among the countries of the region, as seen in < 2% in the case of Uruguay and El Salvador, and 50-60% in the case of Ecuador and Venezuela. In the Caribbean several island or island groups are less than 1% protected, while at the other extreme over 66% of the Dominican Republic, the Cayman Island and the Turk and Caicos Islands are under protection. Moreover, extractive reserves are included in the accounting. Notably the percentage of protected area in the predominantly temperate countries of the Region (7.5%) falls way below that for the tropical countries (20.9%), although Chile has 19% of its land surface under protection.

In addition to national protected areas, LAC possesses around 100 MAB reserves, 250 Ramsar sites and 130 National Heritage sites, some of which overlap spatially with national parks and other reserves. MAB reserves are structured so as to allow economic activities in the buffer zone, while maintaining the core area under strict protection. The past 10 years, moreover has seen an increasing trend for the private sector to invest in biodiversity conservation, at many different spatial scales. Some notable examples at the larger end of the scale are Karukinka in Tierra del Fuego in Chile (270 000 ha) acquired by a private investment bank (Goldman Sachs and today managed by WCS, and Parque Pumalin (300 000 ha) in southern Chile, acquired by a private owner (D. Tompkins).

Despite the huge and commendable efforts in LAC in terms of setting land aside for protection, this is often woefully inadequate with regards to the distribution and abundance of individual ecosystems in a country, as is the level of implementation and management in many parks. With regard to their management, many national parks and reserves are understaffed and with inadequately trained rangers. Likewise, many MAB reserves are poorly administered, and not functioning to their full potential. With regards to their distribution, many protected areas were set up as national parks primary on the basis of their scenic and recreational values, or were located in remote territories not considered to have any immediate economic value (Armesto et al., 1998). Three notable cases are mentioned of what is a common phenomenon. In Chile with over 19% of protected land, 60% of the heavily forested region in the southern part of the country is protected, whereas less than 5% of the Chilean biodiversity hotpot in central Chile comes under national protection (Arroyo and Cavieres, 1997). In Brazil a huge part of the protective effort falls in the Amazon basin, there being notable deficits in the species-rich Cerrado and "Campos Rupestres". The high number of Conservation Units in Brazil (382 in total with 290 Federal) is truly impressive. With the support of the Brazilian Government, GEF, the World Bank and WWF, 50 million hectares, including samples of all 23 Amazonian eco-regions, will be protected by 2012, signifying 12% of the conservation units (MMA, 2002). The neighboring Cerrado (2 million km^2 in central Brazil) and Caatinga (the 740 000 km^2 semi-arid biome in northeastern Brazil) have less the 6% and 2% of the conservation units (Cavalcanti and Joly, 2002; Silva et al., 2004). For the Atlantic Forest, classified as a Biodiversity Hotspot by Myers et al. (2000), 21% of the remaining area is officially under strict protection in 224 public protected areas (108 national and state parks, 85 federal and state biological reserves and 31 federal and state ecological stations and reserves) and 443 private reserves (approximately 1 000 km^2). In

Argentina, 4 598 km^2 are under protection in 60 protected areas of various categories, representing about 21% of the original Atlantic Forest in Misiones province. There are eight protected areas totalling 1 392 km^2 in the Atlantic Forest portion of eastern Paraguay, covering less than two percent of the original extent (CI, 2007). The same unbalanced situation is observed in the State of São Paulo, where less then 7% of the Cerrado is protected. According to the World Commission on Protected areas, less than 1% of the Pampas of Argentina are protected.

In general it may be concluded that wet forested habitats throughout LAC enjoy better protection than dry forest, semi-arid and arid scrublands and grasslands. The situation clearly calls for a more balanced conservation effort across the ecosystems in LAC.

Conservation measures in marine habitats in LAC vary from well delineated marine parks, to areas of sustainable use, to nothing at all. Aided by the warm seas and abundant and colorful marine life engaging ecotourists, several marine parks are found throughout the Caribbean (e.g., Statia Marine Park on Eustatius Island, The Tobago Cays Marine Park in the Grenadines, Saba Marine Park, Bonaire National Marine Park, Arikok National Park of Aruba, East End Marine Park). East End Marine Park will protect the largest island barrier reef system in the Caribbean. However, it would seem that marine parks are more difficult to implement in the colder southern and less charismatic waters of LAC. There are many declared Nt-MPAs in the coastal realms of LAC´s countries. Nevertheless, in many cases they represent "paper NT-MPAs", lacking monitoring schemes and not being associated with scientific programs. Most of LAC depends, in one way or another, on marine coastal resources. Local people (sea users, fishers, other stakeholders) often see Nt-MPAs basically as government intrusions in their coastal areas, via closure or restrictive measures. The tendency is not to conform to the law. A recent study (MacClanahan, 2008) indicates that there are about 50 million small-scale artisan fishermen around the world. An educated guess would suggest that around 10% are inhabitants of LAC. Such fishermen capture about 30 million tonnes of fish annually, mostly for direct consumption as compared to the 40 million tonnes captured annually via industrial fishing. Small-scale fishing consumes about five times less oil (2.5 million tonnes per year) than industrial fishery fleets. Also small-scale fishers discard about 5-6 times less "bycatch fishes" (around 1.5 million tonnes annually) than industrial fleets. These numbers indicate that small-scale fishing activities are critical socio-economic (and cultural) activities for millions of coastal inhabitants (fishers, families, local towns) around the world in a sea where there are no ownership boundaries. All this implies that the sustainability of coastal resources over time is critical for the conservation of marine species. The same can be said regarding ecosystem functioning and biodiversity.

Given the above situation, LAC urgently needs to develop a Marine Conservation and Sustainable Resource Use System. For this, the different legislations, sea-cultures and food-economic needs must be taken into account. There is no single answer to this problem. The most successful cases (Chile, Mexico; see Castilla and Defeo, 2005; Defeo and Castilla, 2005) indicate that the ideal solution is the integration of coastal networks that include several biodiversity conservation and managed systems. For instance, bottom-up designed coastal networks including territorial User Rights for Fisheries (TURFs, for small-scale artisan fishers or shore food gathers) in the form of Managed and Exploitation Areas for Benthic Resources (MEABRs), such as those developed in Chile together/jointly with Nt-MPAs, Marine Parks, Reserves (genetic conservation, for research, for tourists, for education) increase the rate of marine biodiversity conservation success. Furthermore, it has been recently demonstrated in Chile (Gelcich et al., 2008) that areas dedicated exclusively to the sustainable use of coastal resources, if well managed, can also perform as conservation units for marine biodiversity. Local people, coastal marine cultures, traditions, local ecological knowledge (LEK) and needs of users are critical aspects when developing such plans. In LAC (i.e. Cuba, Chile, Mexico, Brazil; also see World Bank 2006, Report 36635-GLB) the successful examples of marine biological conservation developed jointly/embedded within areas dedicated to the sustainable use of coastal resources (managed areas) need to be replicated over the entire region as part of marine coastal management and biodiversity conservation programs.

While there are clearly many protected areas in LAC, albeit, badly distributed with respect to the contributions of each ecosystem, studies to evaluate the real contribution of existing protected areas to the conservation of regional biodiversity and ecosystem services are still few. This crucial information is hindered by a lack of good knowledge of species distributions and incomplete or no checklists at all for protected areas. It is exacerbated by the lack of scientists in LAC who are trained as taxonomists (cf. Simonetti, 1997) and conservation biologists (cf. Rodríguez et al., 2006) and who are capable of identifying plants and animals from many different taxonomic groups, already alluded to earlier in this Assessment. In any case, studies of this kind exist for a few animal groups (e.g. Yahnke et al., 1998), and central Chilean plants (Arroyo et al., 2000). The huge number of plant species in relation to animal species in LAC, deems this kind of work much more complex and slower in plants. More sophisticated GAP and related analyses have now been completed for vertebrates and plants in Mexico (CONABIO-TNC-PRONATURA, 2007; Ceballos, 2007), vertebrates in Chile (Toginelli et al., 2008), and plants in the Atacama desert region (Squeo et al., 2008). Informing government authorities on information gaps is critical (Rodríguez and Young, 2000).

Parsimony Analysis of Endemicity (PAE) have become very popular in LAC, where they have been carried out at various spatial scales, according to whole floras and faunas, or on the basis of individual taxa (e.g., Da Silva and Oren, 1996; Posadas, 1996, Posadas et al., 1997; Cavieres et al., 2002; Luna et al., 1999; Rovito et al., 2004). All these various studies tend to indicate that actual protected areas are generally inadequate, and that the optimal spatial configuration for reserves in a world without restrictions would be quite different. Unpublished studies in the northern part of the Mediterranean area of Chile on the large genus *Senecio* and where protected areas have been well collected, indicate that around 35% of the species do not fall into any protected area, and that the possibilities of creating new state parks to adequately protect the remaining widely scattered species across the landscape is out of the question. A network of smaller scale reserves on private lands and efforts to save the remnants of the original vegetation matrix on productive lands, linked by corridors to major parks and reserves constitutes the only viable option for adequate protection of the flora of the Central Chilean Biodiversity Hotspot and this is likely to the case in other types of vegetation like the Cerrado. One of the crucial points here is to convince land owners to collaborate, and governments to provide incentives to the land owner. This use of the tax payer´s money is totally justified for this purpose on the grounds that such conservation measures benefit all of society, either directly or indirectly.

In any case, as in the sea, some of the best success stories in conservation in LAC have involved lands that are used by local populations. An interesting case is seen in the Andean Páramo Project, which will be executed in a network of key pilot sites along the South American Páramos from Venezuela to Bolivia. The design process involves a series of participatory workshops with a multidisciplinary team, including the local population and the incorporation of local knowledge and views as the basis for planning (Lambí et al., 2005), drawing in turn on a profound knowledge of ecosystem functioning obtained over many years of basic research by scientists at the Universidad de Los Andes in Venezuela (e.g. Vuilleumier and Monasterio, 1986).

Ex situ conservation

The effectiveness of ex situ conservation of wild species has generated considerable debate given the space required and the costs of maintaining collections sufficiently large so as to ensure genetic integrity. Botanical gardens can be an important part of a conservation strategy for many species, when strategically placed in relation to a country´s ecosystems, while at the same time performing the dual role of biodiversity education. Linked together in a network (see for example the Argentinian Botanical Garden Network: www.bgci.org/argentina_esp/botanic_garden_esp) botanical gardens can be a powerful tool for conservation in the sense of encouraging new botanical gardens to develop.

Considering South America, Brazil, Argentina and Colombia are the countries containing the most botanical gardens. All other countries in South America have less than 10 botanical gardens (Arroyo et al., 2003) and many of these really do not really deserve this distinction. Several important botanical gardens are found in Mexico, Central America and the Caribbean. Given the number and location of the present botanical gardens, it is very unlikely that all ecosystems are adequately, if some at all, represented among LAC´s botanical gardens. Yet, there could be surprises if the information were available.

At the research level, ecological restoration is allied to ex situ conservation in that both require knowledge of seed germination and soil properties. The creation of a germplasm bank of microorganisms for inoculating plant material to be used in the process of ecological restoration should be a priority for LAC. Conservation *in vitro*, that is, via maintenance of tissue banks, should be regarded as an alternative when seed production in a species is scarce or when serious problems for propagation exist. In addition, it is expensive and risky.

In LAC, where biotechnology has developed extensively, tissue culture and gene banks are seen as a viable conservation measures. Tissue culture simultaneously has the advantage of reducing human pressure on natural populations, which is usually the ultimate cause of conservation problems. The technique most widely used is micro-propagation; transgenic plants resistant to pests and disease have been already been created. Without any doubt, Brazil and Argentina are the leading countries in these research areas, but most plants being studied at this stage or found in large germplasm banks in a variety of forms, including seeds, pertain to domesticated plant species. Important germplasm centers are the Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica (CATIE); Centro Internacional de Agricultura Tropical (CIAT) in Colombia; Banco Nacional de Germoplasma Vegetal in Chapingo and Centro Internacional de Mejoramiento de Maíz y Trigo, Mexico (CIMMYT); Centro Internacional de la Papa, Peru (CIP); Centro Nacional de Pesquisa de Recursos Genéticos e Biotecnología (CENARGEN), Instituto Nacional de Investigação Agrária e das Pescas (INIAP), International Bank of Coconut Genes, International Plant Genetic Resources Institute (IPGRI), Brazil; Instituto Boliviano de Tecnología Agropecuaria, Programa de Investigación de la Papa, Bolivia (IBTA-PROINPA); Instituto Nacional Autónomo de Investigaciones Agropecuarias, Ecuador (INTA); Instituto Nacional de Tecnología Agropecuaria, Argentina; Instituto de Investigaciones Agropecuarias, Chile (INIA). This list of institutions is not exhaustive.

Chile, in conjunction with the Royal Botanical Gardens, Kew has developed cryoprotection methods for the seeds of desert species, and the Latin American and Caribbean Association of Botanical Gardens has created a seed bank. There are, nevertheless, limitations to this last kind of ex-situ conservation in tropical LAC countries where seeds are often recalcitrant. In all, clearly, there are thousands of threatened plants in LAC that are not found in any germplasm bank or botanical garden.

2.4.3. Cases studies of sustainable management and conservation in LAC

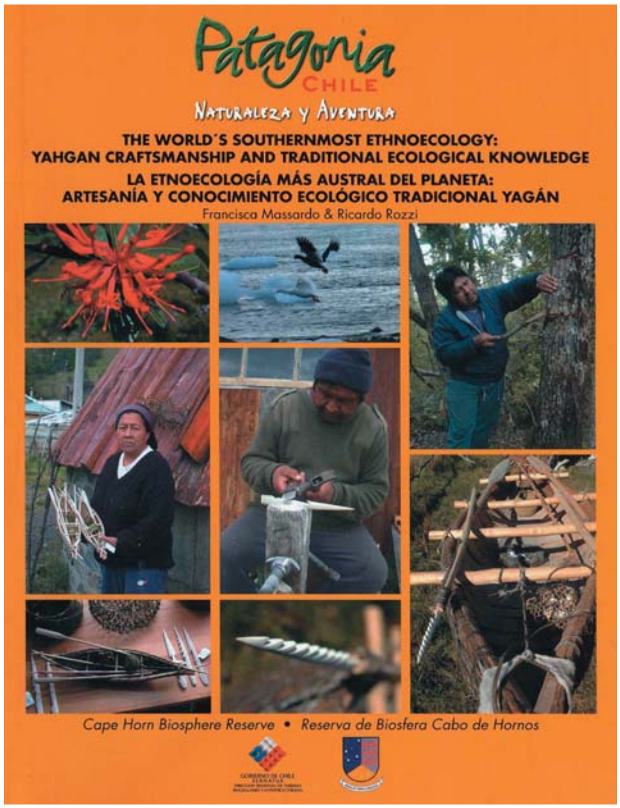


Figure 23. Book cover that combines ethnoecological research and ecotourism at the Cape Horn Biosphere Reserve, in southern Chile. The book was prepared through a collaboration between members of the Yahgan indigenous community and scientists at the Omora Ethnobotanical Park, and published with the support of the Chilean Government, the National Tourism Service, and the University of Magallanes. From Massardo and Rozzi (2006). See Box 1.

BOX I

THE CAPE HORN BIOSPHERE RESERVE: AN INTEGRATED RESEARCH PROGRAM FOR PROMOTING SUSTAINABLE DEVELOPMENT AT THE SOUTHERN TIP OF THE WORLD

The Cape Horn Biosphere Reserve (CHBR) protects one of the world's most pristine ecoregions, the Magellanic subantarctic rain forests found at the southern end of the Americas. It includes the archipelagoes south of Tierra del Fuego, and the fjords, ice fields and glaciers on Darwin Cordillera, 1 000 kilometers north of the Antarctic Peninsula. With five million hectares of marine and terrestrial ecosystems, it is the largest biosphere reserve in southern South America. CHBR has the following attributes relevant to the sustainable use of biodiversity and local socio-economic development. Its creation in 2005 resulted from a six-year collaborative effort between the regional government and an interdisciplinary team of ecologists, artists, and humanists lead by the Omora Botanical Park. Subsequently, a set of ten guiding principles were identified: 1] inter-institutional cooperation, 2] participatory approach, 3] an interdisciplinary integration of sciences, philosophy, arts, and policy, 4] networking and international partnership, 5] continuous communication via the media, 6] identification and implementation of flagship species, 7] ecologically guided field activities involving "direct encounters" with human and nonhuman beings living in their habitats, 8] economic sustainability and ecotourism, 9] territorial planning and administrative sustainability, 10] conceptual sustainability based on continuous long-term in situ research for conservation. The CHBR initiative seeks ways to translate ecological research into conservation actions. Omora Park is a Long-Term Research Site of the Institute of Ecology and Biodiversity (IEB). Students work as specialized guides, and help educating others guides for sustainable scientific tourism in the austral region. This program has diversified tourism thematic areas in Cape Horn through the preparation of guidebooks and training courses for tourist guides with the support of the Chilean Government such as: "The World's Southernmost Ethnoecology: Yahgan Craftsmanship and Traditional Ecological Knowledge" (Figure 23) based on guided visits that interrelate the biological diversity of Cape Horn and the indigenous Yahgan culture, linking this appreciation to the current Yahgan handcraft industry where tree bark, rushes, and whalebones are still used, and "Tourism with a Hand-Lens in the Miniature Forests of Cape Horn" based on the innovative concept of exploring the beauty of the diverse lichens, mosses, and liverworts of the world´s southernmost forest and tundra ecosystems. This new type of scientific tourism has enhanced appreciation of subantarctic biological and cultural diversity, while at the same time providing a sustainable source of income for local communities in the Cape Horn Biosphere Reserve. A new phase, involving the ecotourism industry in the development, maintenance and use of Omora Park has just begun. International courses are being developed through a partnership with the University of North Texas (UNT) and IEB and other institutions as an additional means of sustaining the initiative.

BOX II

RATIONAL MANAGEMENT OF MARINE COASTAL BENTHIC RESOURCES IN CHILE AND ADD-ON EFFECTS ON CONSERVATION AND BIODIVERSITY

Resource management and preservation are two ways of using natural systems. In the first, intervention by governments is made to sustain/maintain the exploitation of a particular resource (or set of resources) over time for human-well being. In the second, intervention by governments is made with the aim of protect/conserving natural systems (populations, communities, ecosystems). In marine systems, where individual property rights are non-existent, both kinds of interventions are needed regarding the use of common pool resources/systems. This is an importance difference in relation to conservation on the land. The management of benthic coastal resources (invertebrate, algae) in Chile has evolved from a period of unregulated access to resources, before the 90´s, to the present exclusive territorial access rights system ("Management and Exploitation Areas for Benthic Resources": MEABRs). MEABRs are spatial units of inshore sea bed that are allocated to organized communities of artisan fishers for a certain number of years. In the past 15 years this policy has rendered positive effects regarding the stabilization in the use of same previously overexploited resources. Today there are more than 350 MEABRs (covering over 1 000 km^2) managed and protected by communities of fishers. Preliminary evidence indicates that marine biodiversity has increased within some of these units when compared with adjacent open access areas. The increase in biodiversity is reflected in both benthic species targeted for use and non-targeted species, such as mobile fishes, which seem to be using MEABRs units as refuges. This example suggests that there are ways to combine rational extractive management plans for marine resources together with add-on benefits for conservation and biodiversity sustainability. Active bottom-up participation of artisan fishers plays a critical role here. Marine Parks or no-take Marine Protected Areas (nt-MPA) will always be welcome. However, under coastal management system implemented in Chile the latter are seen more as ancillary conservation means. A coastal network of marine biodiversity Parks/Reserves interspersed with well controlled MEABRs is considered to be the ideal management/conservation strategy for the coasts in LAC´s developing countries by the World Bank

2.5. THE RESOURCE BASE FOR BIODIVERSITY RESEARCH IN LAC

2.5.1. Human and institutional resources

Because biodiversity science covers many different research areas, it is not easy to arrive at a quantified assessment of the strength of the LAC research community in the type of assessment carried out here. However, there can be no doubt about the level of interest and vigor in Biodiversity science in the region. Take, for example, a sample of membership strength in some of the main scientific societies (as available in the Web). For Botany, the Brazilian Botanical Society has 2701 (www.botanica.org.br), the Colombian Botanical Society, 290 (www.unicauca.edu.co/acb/index.php), the Chilean Botanical Society, 106 (www2.udec.cl/~botanica), and the Argentina Botanical Society, 510 members (www.botanicargentina.com.ar/pdf/circular3_06.pdf). Although the number of members is not given, there were over 2 900 authors on papers presented at the 2007 Mexican Botanical Congress, mostly from Mexico. Additionally, in the plant sciences in general, the Asociación Latinoamericana de Botánica (ALB) is a very active. For Ecology, the Argentine Association for Ecology Society has 955 (www.asaeargentina.com.ar/socio_buscar.php), the recently created Mexican Scientific Society of Ecology (SCME) has 200, and the Chilean Ecological Society, 141 (www.socecol.cl/) members. Marine scientists have their own organizations, as the Asociación Latinoaméricana de Ciencias del Mar (ALICMAR) which, together with the Comité Oceanográfico Nacional (CON) de Cuba, will organize the upcoming VIII Latin American congress. Conservation biology is represented by the Asociación Latinoamericana de Conservación y Manejo de Vida Silvestre, a recently created and still small society, which is about to organize the Ist Congreso Latinoamericano de Rehabilitación de Fauna Marina. Several countries in LAC have active limnological (e.g.

Chile, Argentina) and zoological societies (e.g., Cuba, Mexico). The Sociedad Cubana de Zoología is organizing the 2008 Congreso Latinoamericano de Herpetología. There are also many specialized societies such as Asociación Latinoamericana de Malacología, which is leading up to the VII Congreso Latinoamericano de Malacología, the Asociación Latinoamericana de Micología, leading up to its sixth Latin American congress, the Sociedad Latinoamericana de Agroecología (SOCLA), the Sociedad Latinoamericana de Biología, and the Sociedad Latinoamericana de Fitoquímica, to name a few. More than 2 000 persons assisted the at the II Congreso Latinoamericano de Áreas Protegidas, held in Bariloche in 2007. All this societal activity, which underestimates what is going on in the region, indicates wide research coverage across the taxonomic and ecological spectrum and a huge potential for biodiversity science in LAC.

Turning more specifically to research, biodiversity science in LAC is mostly carried out in university departments and faculties, far too many to list here. Importantly, a number of Centers of Excellence dedicated specifically to biodiversity science and others with a heavy component of biodiversity science have emerged in Latin America (some quite recently), indicating political recognition of the importance of this area of science. A sample of the more important centers in terms of quality of scientific productivity/infrastructure, roughly from north to south are the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), Instituto de Ecología, UNAM, and Instituto de Ecología, A.C., Xalapa, all in Mexico; Institute of Ecology and Systematics in Cuba, Instituto Nacional de Biodiversidad (INBio) in Costa Rica; Instituto Venezolano de Investigaciones Científicas (IVIC) and the Instituto de Ciencias Ambientales y Ecológicas (ICAE), Universidad de Los Andes both in Venezuela; Smithsonian Tropical Research Institute, Barro Colorado Island, Panama; Instituto de Investigación de Recursos Biológicos Alexander von Humboldt in Colombia; Institute of Ecology and Biodiversity (IEB)

BOX III

MEXICO'S NATIONAL COMMISSION FOR THE KNOWLEDGE AND USE OF BIODIVERSITY (CONABIO) (WWW.CONABIO.GOB.MX/

CONABIO, an important center of knowledge on biodiversity and its uses, and a model that has received praise world-wide, was created by Presidential decree in 1992. Ever since its creation CONABIO has become an indispensable institution for Mexico and adjacent countries, particularly in Central America. Its central goals are: creating and maintaining a National System of Information on Biodiversity, SNIB; supporting research to develop and maintain SNIB; and advising all sectors of society (public, private, social) on matters related to biodiversity by making all relevant information readily accessible to users. Operationally, CONABIO is an organization dedicated in first instance to undertake applied research (under the responsibility of its own staff) based on its comprehensive data bases, while promoting basic research that is carried out by the scientific community with expertise in systematics, ecology, geography, and socio-economics applied to biodiversity conservation. To this latter effect, CONABIO has a sustained program of call for proposals and grants financial support for research on a competitive basis. The results of this program are diverse, ranging from assessments of the conservation status of targeted critical ecosystems, such as mangroves, and species such as the monarch butterfly, as well as of selected regions such as the Meso American corridor. CONABIO also works to compile and generate information necessary to address a multitude of problems related to biodiversity, and to develop human capacity in bioinformatics regarding biodiversity. Currently CONABIO's National System of Information on Biodiversity contains specimen-based information (reliable species identity and geo-referenced collection data) corresponding to about 6.5 million specimens. Such information was captured directly from specimens belonging to the country's scientific collections, or repatriated from specimens deposited in foreign institutions. CONABIO's virtual herbarium presently holds 1.26 million records of vascular plants from more than 80 herbaria in México, USA and other 25 countries. Similar types of information have been compiled for other groups of organisms. Such information, when computerized, becomes a powerful tool for a variety of purposes, ranging from predictions of the potential area of distribution of species to predictions concerning climatic change; the definition of areas of varying probability of occurrence of diseases, such as hanta virus (given the accurately known and inferred distribution of the rodents that operate as vectors of hanta virus); assessments of risks associated to genetically modified organism (GMO) introductions, as a function of the areas of distribution of wild relatives of such GMOs; modeling of the potential areas of impact of introduced pests (such as the cactus moth, *Cactoblastis cactorum*, given the distribution of its host plants, cacti of several species, mainly *Opuntia* spp.), and development of campaigns to prevent establishment or expansion of such pests. Such digitized information, in addition of being used for applied or fundamental research, is being used for international research, such as Mexico's collaboration with the *Encyclopedia of Life*, and the international efforts on the DNA barcoding of several groups of organisms. CONABIO has sponsored numerous publications relevant to Mexico, including the natural history of several biological reserves, and publishes the newsletter *BioDiversitas*.

BOX IV

BIOTA/FAPESP: THE VIRTUAL INSTITUTE OF BIODIVERSITY IN BRAZIL (HTTP://WWW.BIOTA.ORG.BR)

As of 1999 the Virtual Institute of Biodiversity has been engaged in the study of the biodiversity of the State of São Paulo, Brazil. The mission of the institute is to inventory and characterize the State´s biodiversity and define the mechanisms for its conservation and sustainable use. All major public universities (USP, UNICAMP, UNESP, UFSCar, UNIFESP), some private universities (PUC, UNAERP and UNISANTOS), research Institutes (Instituto de Botânica, Instituto Florestal, Instituto Geológico, INPE), EMBRAPA Centers, and NGOs (Instituto Socioambiental, Fundação SOS Mata Atlântica, Conservation International and Reference Center on Environmental Information/CRIA) are taking part of the Program. When considering researchers linked to these institutions within the State of São Paulo, there are approximately 400 with at least a PhD, plus 500 hundred graduate students involved in the Program. In addition there are 80 collaborators from other Brazilian states and approximately 50 from abroad. In six years the BIOTA/FAPESP Program supported 80 major research projects –which successfully trained successfully 150 M.Sc and 90 Ph.D students, produced and stored information about approximately 12 000 species and managed to link and make available data from 150 major biological collections. This effort is summarized in 550 articles published, in 170 scientific journals of which 95 are indexed in the Institute for Scientific Information (ISI) data base, including papers in *Nature* and *Science*. Furthermore, the program has thus far published 16 books and two atlases. In 2001, the program launched an open-access electronic peer-reviewed journal, Biota Neotropica for original research on biodiversity in the Neotropical region. In five years the journal is becoming an international reference in its area and is already indexed by the Zoological Record, CAB International, Directory of Open Access Journals and the Scientific Electronic Library Online/SciELO. Last, but not least, in 2002 the program began a new venture called BIO*prospec*TA in order to search for new compounds of economic interest, which has already submitted three new drugs to patent. During 2006 and 2007 the BIOTA/FAPESP researchers, in collaboration with the State of São Paulo Secretary for Environment/SMA and Conservation International, made an extraordinary effort to synthesize its databank in a set of eight maps of biodiversity conservation and restoration priority areas in the State of São Paulo. These maps has just been adopted (SMA Resolution 15/2008) by the State of São Paulo as its legal framework for impact assessment. BIOTA/FAPESP constitutes a rare example of how a large and well planned research effort can be used to set environmental policies of an industrialized area such as the State of São Paulo.

and the Center for Advanced Studies in Biodiversity and Ecology (CASEB) in Chile; Instituto de Biociências (IB) and Museu de Zoologia and Escola Superior de Agricultura Luis de Queirós (ESALQ), Universidade de São Paulo (USP), Instituto de Biologia and Museu Nacional, Universidade Federal do Rio de Janeiro (UFRJ), Instituto Nacional de Pesquisas da Amazônia (INPA), Manaus/AM, Instituto de Biologia (IB) and Núcleo de de Estudos e Pesquisas Ambientais (NEPAM), Universidade Estadual de Campinas (UNICAMP), Campinas/SP, Jardim Botânico do Rio de Janeiro (JBRJ), all in Brazil; Instituto Darwiniano, Argentina, Instituto de Investigaciones Fisiológicas y Ecológicas Vinculados a la Agricultura, Universidad de Buenos Aires (IFEVA), Museo de La Plata, Laboratorio Ecotono, Universidad del Comahue, Universidad de Córdoba, Instituto "Miguel Lillo", all in Argentina. This list is not complete. The accompanying boxes provide details on three Centers of Excellence.

The majority of the above institutions along with many more have highly valuable biodiversity collections. As examples: Herbario Nacional "Lic. Onaney Muñiz Gutiérrez" and Herbario "Prof. Dr. Johannes Bisse" in Cuba, Herbarium of the Institute of Jamaica, Herbario Nacional de Panamá, Herbario Nacional de Venezuela, Herbario Nacional de Colombia, Herbario Nacional del Ecuador, Herbario de la Pontificia Universidad Católica del Ecuador, Facultad de Ciencias Exactas y Naturales, Ecuador, Herbario Nacional de Bolivia, Herbario de la Universidad de Concepción, Museo Nacional de Historia Natural, Santiago, Herbario de la Fundación Miguel Lillo, Herbario de la Universidad de Córdoba, all have highly valuable biodiversity collections. There are also many collections of importance to LAC in foreign herbaria and museums, such as the Missouri Botanical Garden, the New York Botanical Garden, Royal Botanic Gardens, Kew, the Field Museum, Chicago, the Smithsonian Institution, Washington DC, University of California, Berkeley, to name the most important. It is pleasing that these last institutions are seeing it fit to place their specimens

BOX V

THE INSTITUTE OF ECOLOGY AND BIODIVERSITY (IEB) IN CHILE (WWW.IEB-CHILE.CL)

IEB was created under the Chilean Millennium Science Initiative (MSI) in 2006, an initiative financed by the World Bank and in one of five such institutes in Chile across all fields of science. It main financial resources derive from grants from MSI and the Chilean Base Financing Program for Centers of Excellence in Science and Technology, Chile. IEB is organized as a Non-Profit Corporation under Chilean law and as a network of scientists who believe that basic science, ecological theory and the interface between the biological and social sciences in combination are fundamental for advancing in the management of the environment and for social well being. Its lead scientists (12) hold academic positions five in Chilean universities. IEB's mission is to conduct basic and applied research relevant to the environment, train graduate and postdoctoral researchers, and engage in outreach. The overarching question driving IEB's research –how will biodiversity *per se* and processes generating biodiversity respond under environmental change, considering past, present, and future climatic scenarios, and land use change– is approached through three main Research Foci: 1] Palaeoecology and Biogeography; 2] Ecosystems Ecology; 3] Micro-evolutionary Processes, and two Cross-cutting Themes: 1] Global Change Impacts; 2] Conservation and Society. Together scientists conforming IEB have published over 600 papers and written many scholarly books, including many papers in *Science* and *Nature*, as well as two of Chile´s Red Data Books. IEB networks with scientists in some 16 different countries and encourages its graduate students and postdoctoral fellows (ca. 75-90) to undertake short-term training in foreign institutions. IEB uses three research stations in Chile at 30°, 42° and 54° latitude S along Chile, organized into the IEB Socio-Ecological Long Term Research Network. There is negotiated access to two major georeferenced data bases. IEB engages in Masters, Doctoral and Postdoctoral-level training (Chilean and foreign) and offers a significant number of graduate fellowship and postdoctoral positions on a competitive basis, as well as three international courses. IEB is proud of its comprehensive Outreach program centered in the winter-rainfall desert, Mediterranean climate area, temperate rainforest, and subantarctic rainforest areas of Chile. The program relies heavily on the Senda Darwin Foundation, Chiloé and Omora Park, Isla Navarino. Outreach activities include the implementation of workshops on biodiversity for teachers, school children, national park guides; production of books, posters, games and calendars on biodiversity, among others. IEB has forged a working relationship with the press, reflected in many newspaper articles on its activities. It participates actively in national policy-making committees such as the Species Classification Committee and has a close relationship with the Chilean FSC Forestry Certification working group and the Chilean National Environmental Commission (CONAMA). IEB scientists have long-standing working relationships for biodiversity conservation with the private sector in Chile and were involved in the negotiation of a large private conservation gain (80 000 hectares) in Tierra del Fuego. Four major international awards have been received: The Volvo Environment Prize; the BBVA Prize in Research in Conservation Biology; The Mercer Award, Ecological Society of America, The OAS Latin American Award for Young Scientists in Biological Sciences.

online, as seen in the outstanding TROPICOS effort spearheaded by the Missouri Botanical Garden.

Another important near-term resource is the Latin American Plant Initiative (LAPI), which will scan 'type' specimens of Latin American plant species housed in many institutions and make them available online from a website. This project, funded by Andrew W. Mellon, was initiated in 2007.

2.5.2. Field stations and Long-Term Ecological Study Sites

Much biodiversity work throughout LAC relies heavily on the permanent field sites. Many field stations (varying in size and infrastructure) exist in LAC, but these are not linked into a regional network at this stage. Mexico, Brazil, Colombia, Costa Rica and Venezuela are the only countries that have long-term research sites that are integrated into ILTER, the international branch of LTER. Chile is presently undertaking discussions to join ILTER. Mexico forms part of the North American Regional Network of ILTER, while the remaining countries form part of the Central and South American Network of ILTER. Significantly, Brazil has 12 ILTER sites: principal sites are Marica Field Station, Rio de Janeiro representing restingas and coastal lagoons from the northern Fluminense; NUPELIA/UEM, Maringa on the floodplains of the Upper Parana River; Parque Nacional das Setes Cidades/UFPI, Chapadinha, in the Piauí marginal Cerrados in the northeast.

Some important field research stations in LAC are: Estación de Biología Tropical Los Tuxtlas, representing a tropical rain forest ecosystem, and the Estación de Biología Chamela, representing a seasonally dry tropical forest, both in Mexico, The Estación Costera de Investigaciones Marinas (ECIM), Las Cruces, is an important research center for marine biology in central Chile. Station Senda Darwin, situated in the temperate rain forest of Chile and Station Fray Jorge in the winter rainfall desert zone of Chile both have major long-term ecological experiments underway to determine the effect of El Niño on biodiversity and ecosystem structure and functioning (plants and animals). In Brazil the Ducke Reserve, Manaus, the Center for Marine Biology/USP, São Paulo, Fazenda Nhumirim and Base do Lontra, Mato Grosso do Sul and Estação Ecológica do Taim, Rio Grande do Sul, stand out.

2.5.3. Capacity building

The large biodiversity institutes accept many students and postdoctoral associates from other countries in and outside LAC. These institutions also offer special international graduate courses, in addition to regular graduate courses.

Several formal and informal networks organize graduate courses and workshops in the Biodiversity domain. By way of example, La Red de Genética para la Conservación (ReGeneC) offers courses in the area of conservation genetics. The Latin American Plant Sciences (LAPSN), better known as the Red Latinoamericana de Botánica (RLB), has been active in offering graduate courses for students in the plant sciences for 25 years and has proven expertise. It is organized as a consortium of Centers of Excellence in Latin America designed to increase innovative scientific capacity in the plant sciences by providing graduate level training to students throughout the region. Training centers are located in Mexico, Costa Rica, Venezuela, Brazil, Chile, Colombia and Argentina, with headquarters at the Universidad de Chile, Santiago, Chile. This Network has had a major impact in breaking isolation among the Latin American countries and stimulating collaborative scientific efforts for which is received the Tyler Prize.

2.5.4. Education and the press

The Director General of UNESCO, Mr. Koïchiro Matsuura, at the Closing Session of the Symposium BioEd 2000: The Challenge of the Next Century stated:

> A far greater effort in education in biological diversity is needed to create worldwide public awareness of the issues at stake. Only an educated, global constituency for biodiversity can build up the pressure to ensure that we take the path to a sustainable future.

This brings into focus the need for strengthening outreach and education programs on biodiversity throughout LAC and forging strong relationships with the press. It also begs scientists to collaborate directly on these two issues. Scientists conducting fundamental research can ultimately have a great impact on society. Although the impact of scientific discoveries are often difficult to perceive at the time they are made, most discoveries eventually have some direct application or societal impact. This is particularly true in the biodiversity domain, where basic biological knowledge on species and ecosystems has become a fundamental pillar for the tourism industry and has a direct relationship to detecting the impacts of climate change. Knowledge of a country's species and ecosystems by its citizens also fosters national pride and culture, as well as a sense of curiosity for discovery and the unknown. On the other hand, involvement in the process of promoting scientific literacy through outreach activities and press articles is essential if scientists are to retain the public´s trust.

It is pleasing to be able to report that the LAC press has made important headways in reporting scientific research in general. A survey in 2007 by one of us (MTKA) of up to five of the largest newspapers in each of 18 LAC countries (not all had five) revealed 34 newspapers with some form of Science/Technology Page: www.ianas.org/06-07_venezuela/apresentacoes_es.html. Many papers in high impact journals are reported in the LAC press. Nevertheless, research in areas such as astronomy and biotechnology tend to be more frequently reported than the findings of biodiversity science –an omnipresent syndrome, evidenced by the usually greater general public interest in news related to, for example, space exploration, than exploration and discovery on planet Earth, and molecular biology, given its link with human health. One paper widely covered in the LAC press recently is the *Nature* paper "Diversity without Representation" by Loreau et al. (2006). Insofar as public education is concerned, several national science foundations and institutes in LAC provide special funding to develop science outreach activities. Nevertheless, there is still a tendency for scientists in LAC (as elsewhere) to consider participation in outreach and interaction with the press as interference with their mainstream work. Saving and sustainably using the natural capital of LAC signifies a huge task that will require the collaboration of all stakeholders. Scientific research in LAC is strongly funded by public funds. Thus, scientists should see it as part of their overall responsibilities to promote scientific literacy through outreach education and interaction with the press.

3. THE RESEARCH PLAN

3.1. SUMMARY ANALYSIS

The assessment carried out here on Latin America and Caribbean biodiversity and biodiversity research leaves little doubt that the region *is the most biologically-rich area on Earth*. Yet the level of biodiversity science throughout the region tends to be unequal and, not surprisingly, different priorities, approaches and levels of infrastructure for biodiversity research exist. *Notwithstanding the latter, the scope of the research shows that LAC has a number of first rate research groups and institutions dedicated to biodiversity research, and institutional arrangements can be of international standard.* Although there are no specific analyses of scientific productivity in the biological sciences for the region, perusal at the web pages of the most important centers listed above will show that these are on a par or come close to international centers in the developed world. The level of biodiversity science in LAC has increased notably in the past 10 years, as a result of the requirement of several national research councils to publish in ISI journals and accredit ISI citations when applying for funding.

In biodiversity science in LAC today, we see a great amount of activity and approaches covering the spectrum from the very basic work, to research on mainstream biodiversity research questions. *Perhaps what is most notable is the lack of* *instances where LAC scientists to get together to hammer out conceptual issues and frameworks in their specific research areas from time to time by sitting around the table for a couple of days.* Those scientists who have come to understand the value of this mode tend to interact with networks of scientists in the USA, Europe and other developed countries. It seems critical to promote greater interaction among the scientists of LAC within the region itself, for which the region should pin point its leaders and call on them. *Likewise the time is ripe to stress the value of compiling data sets for the region and undertaking Regional analyses.*

The Assessment showed, by way of two case studies, that integrative approaches in biodiversity science that take research beyond the traditional domain of the biological sciences have emerged in LAC. In addition, a number of research institutions in LAC have actively engaged in outreach, and interactions with the press.

There is a need in the LAC biodiversity research community to get up to steam with the information age. Biodiversity scientists, whether in the areas of taxonomy or ecology, are increasingly required to understand complex processes, which require the management and use of large data sets and/or long-term series. This requires a new kind of expertise, and a move away from individual endeavors to team and collaborative work.

More specifically, in the area of the *discovery of biodiversity* it was seen that large and important tropical countries of the region with huge amounts of biodiversity, such as Brazil and Venezuela, still lack complete checklists of plant species, yet at the same time, there are advances comparable to many developed parts of the world, as seen in the catalogue of vascular flora of the South Cone, about to appear, showing that major efforts are possible within the region.

In a similar vein, while two countries (Mexico, Costa Rica) have succeeded in "nationalizing" and/or centralizing their biodiversity information with sustained financial support from their governments, making it freely available online, at the other extreme, other countries lack electronic biodiversity data bases or, where they exist, governments and/or the national science councils have not seen it a priority, or have not been able to develop workable arrangements to assure that existing geo-referenced biodiversity data are placed online and made freely available to scientists at large. The discovery of biodiversity in the many unusual habitats in LAC and of microorganisms as well as below-ground organisms has only just begun.

In the area of *evolutionary and ecological processes* that produce, sustain and are responsible for the distribution of biodiversity, the level of science in ecology, evolutionary ecology and related disciplines in the more developed countries of LAC is such that scientists are rapidly able to assimilate critical research questions and publish in high impact journals. However, there is still a tendency to carry out research in isolation, with little comparative work across the main ecological gradients represented in the region, and still scarce linkages with global-scale efforts, and major international biodiversity programs such as DIVERSITAS.

Two evident problems in this area of biodiversity research is that funding is usually insufficient to ensure that critical data sets are taken in such a way as to allow revisiting sites in the future and to maintain field stations and their instrumentation. While research on the impacts of climate change, land use practice and invasive species is underway, scaling up from such studies tends to be limited due to the lack of open-access georeferenced data bases and limited access to climatic and other related data in some countries.

With respect to molecular and genomic approaches, the expertise and intellectual capacity exists in several Latin American countries, and there are now several well equipped laboratories. Some research groups in this research area have recognized the value of networking with foreign researchers as a means for progressing faster.

In the important area of *ecosystem services* and the *socio-economic valuation of biodiversity* the assessment shows a tepid, but very promising development.

In the area of *conservation and the sustainable use of biodiversity* the assessment shows that the scientific effort has basically failed in guiding the governments of LAC with regard to where protected areas should be placed. The possibility of downgrading existing parks and reserves and replacing them with other areas is not practical, nor would it be accepted by a society that has come to value its protected areas for recreation and scenic beauty and the tourism industry. In addition, there is an urgent need to understand the potential for conservation of biodiversity and ecosystem services in the agroscape or managed matrix.

Overall, the objective of the ICSU-LAC Biodiversity Research Program should be to promote international-level science of relevance to society. It should also be seen as a window of opportunity to expand the scope of biodiversity science in the region, while at the same time preparing scientists to work in a collaborative mode.

3.2. PRIORITY RESEARCH THEMES

In accordance with the Assessment and summary diagnosis above, the ICSU-LAC SPG on Biodiversityidentified the following research themes as priorities for the ICSU-LAC Biodiversity Research Program. Additional research needs can be found in the relevant sections of the Assessment.

1. Development of georeferenced data bases and completion of biological inventories for testing hypotheses on the large-scale planetary patterns of biodiversity and for detecting the impacts of global change drivers, climate change included, on biodiversity, with emphasis on the major knowledge gaps, as well as the opportunities provided by LAC´s model ecological gradients.

We see this priority being projected at different spatial scales, according to the level of existent knowledge and infrastructure.

At the Regional level, SPG on Biodiversity considers it is imperative to develop testable hypotheses regarding patterns of species richness, endemism, and functional diversity in marine and fresh-water biodiversity, so as to complement what is known for terrestrial habitats. This necessarily will entail the development of electronic data bases, and online capacity. Such data bases obligatorily should include information on the conservation status and sustainable use values of marine and fresh-water species. Studies at the country level are less attractive in this Program, as the aim is to detect regional patterns.

At the ecosystem level, SPG-2 concluded that advantage should be taken of ongoing work in the above-treeline flora of the entire South American Andes, covering subantarctic to tropical latitudes, for testing hypotheses on the latitudinal distribution of biodiversity and modeling the effects of climate change. The assessment showed that the alpine belt is one of a handful of ecosystems in LAC for which we possess detailed distributional knowledge of the entire flora. The steep altitudinal gradients of the Andes constitute an outstanding model for determining species responses to climate change in a wide range of plant species, genera and families. Subjected to a large variety of climates along their huge latitudinal range, the high Andes are an untapped goldmine for this kind of work.

At the country level, we recommend strengthening the research efforts of CONABIO (Mexico) and Biota Neotropica (Brazil), in the understanding that expertise will be extended to other countries/states, and that the number of taxonomic groups of organisms considered by these programs increases. Increasing the delivery capacity of these programs would greatly increase the scope of modeling the impacts of climate change on biodiversity and conservation modeling at the level of species.

The SPG on Biodiversity strongly recommends that efforts are made to see completion of new annotated checklists of vascular plants in the region so as to gradually move toward a full inventory of this group of organisms in LAC and thus not have to rely on estimates as at present. Such major checklists, apart from the basic botanical information, should include information on the conservation status and sustainable use value of the species as far as possible, and be peer-reviewed and published. A logical place to start would be Brazil; however new Subregional efforts following the model of the Southern Cone and the Meso American Flora, would also be more than welcome. This information, once compiled, would enable testing a myriad of biogeographical hypotheses. If developing these checklists means training more taxonomists, then this should be fully supported (see section on Capacity Building).

All the specific research items outlined above should be planned so as to contribute to the following *added value research objective*. In our view there is a need for developing synthetic biodiversity metrics that go beyond the hotspot and FF concepts. This should integrate information on species richness, endemism, global scarcity, phylogenetic diversity, species interaction diversity, ecosystem service values and, to the extent possible, functional diversity.

2. Undertake syntheses of molecular phylogenetic information for the region with the aim of detecting phylogenetic patterns and phylogenetic diversity in the biota of Latin America and Caribbean.

The assessment showed that the time is ripe to analyze the huge amount of phylogenetic information that has accumulated on groups of organisms whose distributions are centered on LAC so as to test key hypotheses of theoretical relevance and practical application. If this could be achieved, LAC could be the first region in the world to determine the diversity of clades over a large part of the latitudinal gradient, along with investigating such questions as latitudinal differences in speciation rates and phylogenetic diversity. This research at the same time would provide important information for improving present biogeographical schemes for the LAC region in marine, freshwater and terrestrial biodiversity. Much of this research can be achieved via a workshop mode.

3. Evaluation of the ecosystem services on managed and unmanaged landscapes.

The large amount of protected land in LAC contributes numerous ecosystem services to the planet´s Life Support System. Nevertheless, formal studies of ecosystem services whereby such services are quantified as part of the national accounting are few and thus should be encouraged. Much of LAC´s biodiversity on the other hand, is found primarily today on managed landscapes. Such remaining biodiversity in the form of forest islands and stream protection belts needs to be evaluated for its ecosystem service value in protecting erosion, sequestering carbon and preserving water resources in the context of national accounting. Such studies are badly needed to provide additional arguments for saving hundreds of species of plants and animals found primarily on managed lands in such hotspots as Meso America, Central Chile, the Cerrado in Brazil and the northern Andes.

Studies are also badly needed on some key groups that provide special ecosystem services themselves. For example, SPG on Biodiversity recommends landscape level studies on native plants and animals, with biological control agents (bats, parasitoids, etc.) and pollinators (e.g., bees) as a prime target, in order to detect their value in the protection and pollination of native crops and trees in an ecosystem service context, and to determine their conservation status in the light of anthropogenic impact, such as the recent introduction of several aggressive invasive bee species in the region. Assessing key environmental factors influencing provision of services should be one of the primary goals of ecosystem service research (Kremen, 2005). These studies should incorporate evaluation of leaving vegetation remains in agroecosystems and agroforestry ecosystems, both from a carbon sequestration point of view, and as a source of bee pollinator habitat. On the other hand, early-warning systems on the impact of aggressive bees and harmful introduced pests need to be developed –yet this is an area that is wide open.

4. Consolidation of a network of Ecological Observatories in LAC to undertake experimental studies and long-term monitoring on the impact of climate and land use changes on biodiversity in natural and managed landscapes.

Knowledge of how organisms, natural ecosystems and agroecosystems will respond to climate change, El Niño, and land use change is critical for national planning in agriculture, ecotourism and conservation. Few regions of the world are as ideally set up as LAC to undertake this kind of research. The SPG on Biodiversity feels that LAC should take advantage of several gradients and contrasting ecological situations present in LAC, including: a] the temperate to tropical rain forest gradient; b] the wet-dry gradient, as represented on the east and west slopes of the Sierra Madre Oriental in Mexico, and the east-west coast of South America at around 30-23°S; c] economically important agroscapes, and d] the afore mentioned latitudinal gradient represented by the Andean chain. The research to be undertaken would include focused experiments on the impacts of climate change and land use changes on biodiversity and long-term monitoring of plant phenology and animal behavior, among other variables, as indicators of change.

The first stage would consist in identifying ongoing research capacity, field sites and existing infrastructure via a Regional workshop. As far as possible, the sites should be located in areas where georeferenced data at larger spatial scales are available, so as to allow scaling up. This kind of long-term research requires a strong commitment from governments to provide costly field equipment for monitoring climatic and other variables, and for the maintenance of such equipment.

5. Development of a Regional-scale assessment of the impacts of invasive species on biodiversity in the context of early warning systems.

The assessment showed that knowledge of invasive species in LAC is inadequate in most groups of organisms. Yet it was shown that the probability of the arrival of new invasive species and the spread of others with the region is high, especially with globalization and the increasing level of integration between the countries of the region, potentially signifying loss of native biodiversity and huge economic costs in the long run. Due to complex feedbacks with climate change, Antarctica was seen as one of the most vulnerable areas, and thus should be included in this assessment; this also means being concerned with neighboring subantarctic ecosystems.

The dynamics of biotic interchange begs us to change our ways of communicating scientific findings if they are to be relevant to society. Relying on published lists of invasive species updated, say every 10 years, is no longer sufficient. Far more flexible means of communicating new introductions and results are needed. As we visualize it, a regional scale assessment of invasive species would involve five overlapping stages: a] development of a regional online access data base of alien species in all taxonomic groups, including validation of data by trained taxonomists; b] development of a set of criteria for determining whether particular aliens are likely to be harmful; c] implementation of an Early Warning Online System on Invasive Species; d] ecological work to determine differences in the invasibility of different ecosystems; e] establishment of links with government agencies involved with the control of invasive species.

6. Transference of biodiversity and biocultural knowledge into sustainable economic activities, including any benefits of bioprospection.

The outstanding biodiversity of LAC and the vast biocultural knowledge accumulated by indigenous and other local peoples in LAC, in the face of the present urbanization trends, makes research in coupled human-ecological systems a priority for the region. Saving pristine and semi-pristine ecosystems through non extractive activities or planting native plants (which become magnets for other biodiversity) in cities constitute ways for local people and society at large to reap the multiple benefits of the ecosystem services provisioned by natural and man-made vegetation. High profile projects of this nature can serve to stimulate national and regional pride and provide examples to be followed by other users of the land. This particular area of research requires an amalgamation of biology, sociology, economics, outreach education, the ability to turn biodiversity-based activities into sustainable economic development and, above all, pragmatism. It thus constitutes a major challenge in LAC, but one which is worthwhile facing. This is an open-ended research area that requires willingness on the part of funders to take risks and understand complexity. However, from the social point of view, this research priority is clearly critical for LAC.

We see this kind of research as being most urgent in four situations: a] latitudinally extreme ecosystems where conditions for conventional agriculture and forestry and other economic activities are not possible; b] coastal ecosystems where thousands of local people in LAC depend on marine resources for their livelihoods; c] the interiors of major urban complexes; d] frontier forests and biodiversity hotspots, where losing those ecosystems would signify a huge loss of biodiversity and ecosystem services; e] tropical human coupled ecosystems, where a wealth of traditional knowledge exists on ecosystem management. Research of this kind should incorporate the valuation of ecosystems services, including carbon sequestration and the regulation of water flow, and the evaluation of economic activities that rely on native biodiversity. Several ongoing initiatives in LAC are potential targets for this kind of research.

7. Finding solutions for the implementation of biodiversity conservation measures in managed landscapes and seascapes.

The assessment showed that although LAC has an outstanding number of protected areas, on the land and in the marine realm, where serious research has been carried out, many of these protected areas have been shown to inadequately protect biodiversity; moreover huge imbalance between the protection of forest and the arid/semiarid ecosystems was detected throughout the region. At the same time, the assessment showed that vast areas of LAC´s natural ecosystems are being transformed for agriculture, cattle raising and plantation forestry, to the extent that natural vegetation corridors between protected areas are being progressively obliterated. To make things worse, the integrity of protected areas, many of which are already immersed in seas of managed lands, is now threatened by climate change. All these trends make the incorporation of protective measures in the managed landscape a priority area of research in LAC.

This type of research, like Priority No. 6, requires an integrative approach. For terrestrial habitats, owners of the land must see benefit in engaging in conservation, while at the same time, conservation measures proposed by scientists should aim at producing the best spatial arrangements, and contribute to the overall conservation needs of a country´s ecosystems and species. In the sea, research is needed to determine whether maintaining pockets of protected coast, in a Noah´s arc-like-fashion, increases biodiversity in managed areas and enables maintaing genetic diversity. On the other hand, it is essential to achieve that local peoples tke advantage of the value of such measures, via certification, payment per environmental services protection and other schemes that provede them with income and wellbeing in general. The feasibility and enormous potential of this approach is documented in several instances in LAC, including marine/coastal examples in Chile, the Cape Horn Biosphere reserve, sustainable forest management and certification in Mexico and the Sierra del Rosario Biosphere Reserve in Cuba, as a case study of sustainable management with UNESCO recognition. Priority areas for this research area of the program are arid and semi-arid ecosystems and hotspots, such as the central Chile Biodiversity Hotspot and the Brazilian Cerrado, the Meso American hotspot, the vavilovian Center of the Andean region, and the Caribbean.

8. Development of studies on the ecosystem service value of urban biodiversity.

As mentioned earlier, the growing urban LAC population must be educated about biodiversity so as to empower citizens when it comes to their rights on environmental matters. Undertaking research on the ecosystem services of urban biodiversity opens the door to this need.

3.3. OUTREACH ACTIVITIES

SPG-2 is adamant that all researchers and graduate students participating in projects financed by the ICSU-LAC Biodiversity Research Program, in addition to communicating their results in scientific events, be required to undertake outreach activities outside the academic domain. This can be in the form of public presentations, educational outreach workshops, development of interactive web pages, writing of popular articles, or developing co-teaching partnerships with science teachers in K-12 schools.

3.4. LINKAGES TO EXISTING INTERNATIONAL BIODIVERSITY AND RELATED NETWORKS

Research priorities 1-7 are consistent with the DIVERSITAS Science Plan (www.diversitas international.org/docs/diversitas/diversitassp.pdf.) and the possible implementation of IMOSEB or some modification thereof in the near future (www.imo-seb.net). They meet recommendations of the Millennium Ecosystem Assessment (www.millennium assessment.org) and have direct links to climate change research (www.ipcc.ch).

Research Priorities 1, 3 and 4 could be profitably linked into the following thematic and cross-cutting networks: a] GEOSS (www.epa.gov/geoss); b] NEON (www.neoninc.org); c] ILTER (www.ilternet.edu); d] GMBA (www.gmba.unibas.ch) (see Körner et al., 2007). GEOSS is the product of the GEO-BON group (Scholes et al., 2008), a voluntary partnership of national governments and independent participating organizations. GEOSS is presently undergoing planning under the mandate of DIVERSITAS and NASA. NEON is a continental scale research instrument consisting of geographically distributed infrastructure, networked via state-of-the-art communications supported by NSF-USA. ILTER is a long-standing Long-Term ecological Network with vast experience in setting up long-term experiments in the field. The GMBA is a cross-cutting network of DIVERSITAS dedicated to mountain biodiversity, at present focused on promoting the use of georeferenced data bases as a tool for biodiversity research.

Research Priority 2 has relevance for the Tree of Life Network (tolweb.org).

Research Priority 5 fits well with IABIN, the Inter American Biodiversity Information Network (www.iabin.net), MIREM (Mountain Invasive Species Network) and several ongoing initiatives in Mexico (e.g., CONABIO's invasive species program) and in the Caribbean (www.invasivespeciesinfo.gov/international/mex carib.shtml).

Research Priority 6 is of relevance to the development of Biosphere reserves (www.unesco.org/mab/BRs.shtml) and to PISCO (www.piscoweb.org/) as well as to the remarkably successful and most productive bio-cultural diversity funding agency, the Christensen Fund, especially its global program (www.christensen fund.org).

Research Priority 7 fits well with Conservation International´s work on biodiversity hotspots (www.biodiversityhotspots.org) and with the Nature Conservancy's well regarded work in South America (www.nature. org/wherewework/southamerica).

4. CAPACITY BUILDING, WORKSHOPS, INFRASTRUCTURE AND OTHER NEEDS

4.1 TRAINING

1. Training and integrating taxonomists into various areas of the biodiversity research program. One of the most serious threats to biodiversity in LAC concerns the lack of trained taxonomists. The last situation derives from the competitive nature of science in Latin America today, whereby taxonomy, which normally does result in papers than garner few citations in ISI, is not seen as a viable option for a professional research career.

2. Training scientists with respect to the value of collaborative research, integrative approaches and international networking. Lack of integrative approaches in Latin America are partly a reflection of the more specialized curriculum structure in LAC universities and steps need to be taken to overcome this obstacle and a tendency for its scientists to look to the developed world for research partners and inspiration.

3. Hands-on training for students and professional personnel in data management and other know-how and research methods in centers of excellence outside the region. This kind of training is especially important for the management of sophisticated recording instruments at field sites.

4. Incorporation of foreign postdoctoral researchers and research internships for undergraduates from the developing and developed countries within LAC, and

from developing countries outside LAC. This is fundamental for man powering the program, while at the same time further internationalizing the participant research laboratories

5. Promotion of workshops with the participation of scientists and the press. This kind of activity has proven to be useful for developing close and trusting ties between scientists and the press.

These capacity building actions are strongly directed at expanding the horizons of LAC students and researchers so as to prepare them for doing science in a globalized world and on ever more complex problems, while at the same time taking advantage of the research program to train (and learn from) young scientists from other parts of the region and beyond its doors.

4.2. WORKSHOPS

Because many of the proposed research activities require collaboration between researchers from different countries of LAC, workshops to develop common goals, protocols, and further research proposals will be essential. These initial workshops should be followed by periodic meetings so as to maintain cohesion, introduce new directions and evaluate progress.

The science plan should include earmarked funds for bringing together scientists to develop conceptual frameworks, analyzing existing sets of data and producing scientific syntheses. A specific example is given above (Priority 2). However, this mode should be made available for syntheses in other research areas as well. A contract with the program would include explicit deliverables, such as compilation of data and production of high-impact multiauthored papers within a specified period of time. Latin America has been generous in providing funds to its students and scientists to participate in scientific congresses –while the latter clearly must continue, the time has come to broaden the spectrum regarding expectations and products.

4.3. INFRASTRUCTURE AND RELATED NEEDS

The major centers of excellence in LAC in biodiversity science have fairly well equipped laboratories, numerous graduate students, and some postdoctoral fellows. However, these laboratories are sometimes not used to their maximum advantage because of the difficulty of finding funds to hire well trained technicians and maintain equipment. The greatest infrastructure needs are costly set-of-the-art automated equipment for registering numerous environment variables at permanent field sites; enhanced computer power; high resolution digital imaging capacity, equipment for storing of materials for genetic/genomic analyses, including ultrafreezers for samples of feathers, tissue, or blood; contracts with major providers of climatic and satellite data; and continual upgrading of GIS facilities. There has been a tendency for individual research groups to install costly sensoring equipment, without prior knowledge of what is being done in neighboring countries. There is a great need to develop a network of stations for assessing climate change impacts on biodiversity in the long term –this should be a regional effort and count with regional funding, as for example in Europe, from such institutions as OAS. Piecemeal efforts in the long run will largely fail.

5. RECOMMENDATIONS ON FINANCING THE BIODIVERSITY RESEARCH PROGRAM

The science plan outlined above comprises a set of interlinked yet independent projects that can be set into motion either simultaneously or in tandem. The program could be seen as ambitious –and it is. Our strategy has been that of covering a large amount of relevant ground and hence opportunities, in the hope that at least 50% of the research will be undertaken. For the materialization of some projects, the needs do not go beyond that of holding 2-3 workshops to work on existing data in the literature (e.g., molecular phylogenetic research). In other cases, significant costs in infrastructure, equipment, travel, and manpower (students, postdoctoral fellows) will be needed.

Programs of the kind suggested here rarely start from scratch –rather they are built on existing funding, infrastructure and contacts. However, given that the research proposed here will increase in scope and scale, and will often take institutions beyond their own country borders, existing financing will be insufficient.

Research programs carried out by groups of scientists from more than one country in LAC are intrinsically difficult for Latin America´s national science councils (CONICYT, CONACYT, CNPq) to finance. The items more readily supported are workshops, scientific meetings and short-term training in developed countries. Funding for equipment that must be installed outside the country of origin of the funds is not easily obtained. Nevertheless, large research institutes in Latin America sometimes have resources that can be used as matching funds for international grants. Graduate students and postdoctoral level researchers from other countries should be encouraged to apply for fellowships and positions, respectively, in national competitions in some countries of LAC. Other potential sources of funds in the LAC region are the IAI, OAS. It would be useful to establish formal contact with training networks such as the Latin American Plant Sciences Network (LAPSN), better known as RLB, and CYTED.

Some private foundations in the USA (e.g., Catherine T. and John D. MacArthur, Rockefeller, William and Flora Hewlett, Pew, The Bill & Melinda Gates Foundation, the Christensen Fund) might be interested in certain parts of the program given that it should have a major impact on developing integrative science in Latin America for the benefit of society, while at the same time stressing outreach, data sharing and informatics. Parallel foundations perhaps exist in Europe.

The private sector could potentially be interested in certain aspects of the Biodiversity Research Program, as for example, Microsoft (informatics and communications) and the pharmaceutical industry. Some work is likely to involve major botanical institutions, such as the Missouri Botanical Garden or the Royal Botanical Garden at Kew.

The role of ICSU will be fundamental in leveraging funding. A wholesome strategy would be for ICSU to convince the national research councils of Latin America to jointly fund parts of the program. ICSU and its partners, DIVERSITAS, are presumably far better positioned to do this than any individual Latin American institution, let alone the individual researcher. DIVERSITAS could do much to help incorporate the smaller countries, particularly in the Caribbean, by holding some of their workshops in these countries, and projecting them towards emerging research groups.

Depending on the financing strategy adopted by ICSU, the ICSU-LAC Biodiversity Research Program does not visualize setting up a major central office and maintaining a large supporting staff. Rather, the program needs 2-3 top level scientists to oversee it, set up the guidelines for bidding or some other mechanisms for bringing researchers on board, oversee a fair process, and develop the criteria for technical and financial reporting. This team of scientists should interface directly with the ICSU-LAC office. Assuming that fund raising is spearheaded by ICSU and the funds are managed in the ICSU-LAC office and sent to each research group, one full time position at the postdoctoral level, and a part time administrative assistant would probably suffice to coordinate the program.

An alternative scheme would be for a leading academic institution in LAC with the legal capability and experience in handling and transferring foreign funds to manage and report on the funds, in this case, charging direct costs to cover administrative costs, including any personnel required. Some major biodiversity institutes in LAC are organized as a Non-Profit Corporations, which permits the kind of administrative flexibility that a program of this kind needs.

The cost of implementing the full Biodiversity Research Program, assuming that some counterpart contributions are forthcoming from the participating institutions, is estimated at an average of US$3 million per year.

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GLOSSARY OF ACRONYMS

ABC: Brazilian Academy of Sciences
ALICMAR: Latin America Association of Sea Sciences
BSP: Biodiversity Support Program
CASEB: Center for Advanced Studies in Biodiversity and Ecology, Chile
CATIE: Center for Tropical Agriculture and Higher Education, Costa Rica
CBD: Convention on Biological Diversity
CBOL: Consortium for the Barcode of Life
CENARGEN: National Center for Genetic Resources and Biotechnology, Brazil
CeNBio: National Biodiversity Center, Cuba
CHBR: Cape Horn Biosphere Reserve
CIAT: Center for Tropical Agriculture, Colombia
CIMMYT: International Center for Maize and Wheat Improvement, Mexico
CIP: International Potato Center, Peru
CNAP: National Center of Protected Areas, Cuba
CON: National Oceanographic Committee, Cuba
CONABIO: National Commission for Knowledge and Use of Biodiversity, Mexico
CONACYT: National Council on Science and Technology, Mexico
COP6: Sixth Conference of the Parties of the IAI
ENSO: El Niño Southern Oscillation
FAO: Food and Agriculture Organization
FFs: Frontier Forests
GCM: General Circulation Models
GDP: Gross Domestic Product
GEOSS: Global Earth Observation System of Systems
GIS: Geographic Information System
GMBA: Global Mountain Biodiversity Assessment
IAI: Inter-American Institute for Global Change Research
IB: Institute of Biosciences, Federal University of Rio de Janeiro, Brazil
IBTA-PROINPA: Bolivian Institute of Agricultural Technology, Potato Research Program
ICAE: Institute of Environmental Sciences and Ecology, Venezuela
ICSU: International Council for Science
ICSU-LAC: ICSU Regional Office for Latin America and the Caribbean
IEB: Institute of Ecology and Biodiversity
IES: Ecology and Systematics Institute, Cuba
ILTER: International Long Term Ecological Research
IMOSEB: International Mechanism of Scientific Expertise on Biodiversity
INBio: National Institute of Biodiversity, Costa Rica
INIA: Agricultural Research Institute, Chile
INIAP: Instituto Nacional de Investigaçã o Agrária e das Pescas, Portugal

INiAP: Instituto Nacional de Investigaciones Agropecuarias, Ecuador
INPA: National Institute of Amazonian Research, Brazil
INTA: National Institute for Agricultural Research, Argentina
IPCC: Intergovernmental Panel on Climate Change
IPGRI: International Plant Genetic Resources Institute
ITCZ: Inter-Tropical Convergence Zone
IUCN: International Union for Conservation of Nature
LAC: Latin America and the Caribbean
LAPI: Latin American Plant Initiative
LAPSN: Latin American Plant Sciences Network
LEK: Local Ecological Knowledge
LGM: Late Glacial Maximum
MAB: Man and the Biosphere Program
MEABRs: Managed and Exploitation Areas for Benthic Resources
MMA: Ministry of Environment, Brazil
NEPAM: Center for Environmental Research, Brazil
NHGRI: National Human Genome Research Institute, United States
Nt-MPAs: No-take Marine Protected Areas
OAS: Organization of American States
OMZs: Oxygen Minimum Zones
PAE: Parsimony Analysis of Endemicity
PD: Phylogenetic Diversity
RAPDs: Random Amplification of Polymorphic DNA (conventional molecular biological term)
RCLAC: Regional Committee for Latin America and the Caribbean
RENCTAS: Brazilian National Network Against Wild Animal Trade
SCME: Mexican Scientific Society of Ecology
SINAP: Natural Protected Areas National System
SOCLA: Latin American Scientific Society of Agroecology
TURFs: User Rights for Fisheries
UFRJ: Federal University of Rio de Janeiro, Brazil
UN: United Nations
UNEP: United Nations Environment Programme
UNESCO: United Nations Educational, Scientific and Cultural Organization
UNICAMP: Campinas University
UNICAMP: University of Campinas
USP: University of Sã o Paulo
WCPA: World Commission on Protected Areas
WRI: World Resources Institute
WWF: World Wildlife Fund

ICSU
International Council for Science

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