NATURAL CAPITAL OF MEXICO

SYNOPSIS

CURRENT KNOWLEDGE, EVALUATION, AND PROSPECTS FOR SUSTAINABILITY

COMISIÓN NACIONAL
PARA EL CONOCIMIENTO
Y USO DE LA BIODIVERSIDAD

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Natural Capital of Mexico

Synopsis

Current knowledge, evaluation, and prospects for sustainability

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Presentation

This synopsis has been produced to highlight the core aspects of the first three volumes of Natural Capital of Mexico, *which gives us an overview to identify priorities for future attention, new research areas and options for the conservation and sustainable management of biodiversity in our country.*

In common with the original work, this synopsis is not prescriptive; it provides a significant amount of supporting information which, within a conceptual framework can be adopted by different orders of government to help define public policies with an appropriate balance between two key axes in order to progress toward sustainability: the social welfare of Mexicans and best management practices and conservation of Mexico's natural heritage.

It is already clear, globally, that countries cannot make decisions regarding the major environmental problems that affect us, either relating to climate or to their own natural capital, without the essential support of the best scientific knowledge available. This has been the purpose of Natural Capital of Mexico *and of this synopsis. Such information, which forms the basis for decision making, arises from a knowledge of the country's biodiversity accumulated over more than two centuries in the heart of many national institutions, and from the contribution and experience of hundreds of researchers, compiled, analyzed and updated in this extensive study. It ranges from genetic variability of organisms to the diversity of ecosystems, their ecological processes and environmental services, and also considers the effect that human activities, public policies and regulations have had on the natural heritage of Mexico.*

The conceptual framework used was based in part on the "Millennium Ecosystem Assessment", but has been adapted to our particular circumstances and characteristics. This approach emphasizes the importance of ecosystems for the provision of the goods and services on which humanity depends for survival, and allows us to have a baseline with respect to their conservation status and a clear description of the major threats currently faced by ecosystems in Mexico, how the challenges that arise from these were met in the past and the tasks we have ahead if we are to successfully preserve the natural capital of Mexico.

Ana Luisa Guzmán

Executive Secretary
(2005-2009), CONABIO

Dawn in the Lacandon Forest.

General introduction

Mexico is a multifaceted country, pluralistic and diverse in many aspects. The most distinctive feature of the country is its enormous heterogeneity. Within our territory, we host countless different landscapes, many unique cultures and contrasting social and economic levels. All of this makes us distinctive, and has shaped our character and unity as a nation while also defining the peculiarities of our problems. Diversity, particularly ecological and cultural, is our most valuable feature. However, in our public policies throughout history, we have generally behaved as though this diversity did not exist, and have acted according to the vision of those responsible for shaping national policies based on personal and group interests. This has meant acting on a simplistic and limited concept of our nation, which has had an extremely negative impact on ecology and society and, as a consequence, has been detrimental to the development of the country.

1 *The mega-biodiversity of Mexico constitutes both a privilege and a potential for the development of the country. It is also a responsibility of our society and of the world. However, its management and conservation are extremely complex.*

Nearly two thirds of the world's biodiversity is located in little more than a dozen countries, known as mega-diverse countries. As it is increasingly recognized, Mexico stands out among these as the fourth nation in terms of species richness, and combines this high biodiversity with a great cultural wealth. This is not surprising: cultural diversity on the planet is closely related to biodiversity, as cultures depend on their natural environment and the goods and services it provides.

Furthermore, two major biogeographic zones exist in the territory of Mexico: the Nearctic—of northern affinity—which contributes with a large representation of the species of the temperate zones of the world, and the Neotropical—of southern affinity—which brings many elements of the tropical zone, that have originated from the Amazon Basin. Almost all the climates of the planet are represented in Mexico, and this, coupled with a rugged topography and complex geology, has allowed the concentrated development of examples of virtually all the world's terrestrial ecosystems in less than two million square kilometers.

With over 11 000 km of coastline and territorial waters estimated at 231 813 km^2 (INEGI 1983), Mexico also accommodates an extraordinary marine diversity; unlike any other country in the world it has an exclusive sea, the Gulf of California, which boasts a high biological diversity and marine productivity.

2 *The development of mankind is totally dependent upon ecosystems and the environmental services they provide; nevertheless, we have failed to value them thus far.*

Since its origin, the development and cultural evolution of mankind has depended upon services provided by the biosphere and its ecosystems. Even modern industrialized societies are reliant on the activity of ecosystems that existed in the Carboniferous period (300-360 million years ago). These produced the organic matter from which fossil fuels originated, the foundation of the economic development of mankind in the last two centuries. Consequently, humanity remains, at least in the first instance, fully dependent on the existence of, and access to, ecosystem services.

We normally interact with two major types of ecosystem: natural, such as jungles, forests, mangroves, reefs, etc., and anthropogenic, or modified by mankind, such as agricultural fields, forest plantations, aquaculture systems and also, in some respects, urban centers. These ecosystems, together with their constituent species and genetic variation, comprise that which we describe as biodiversity.

3 *Biodiversity represents the natural capital of the nation and is of equal or greater importance than other forms of capital, such as financial or manufactured capitals. We must promote and adopt a culture which values biodiversity in the context of the development of Mexico.*

Ecosystems are not only reservoirs of biological diversity, but, more importantly, they provide us with goods and services of inestimable value and which are fundamental to our survival and welfare. In addition to providing us with food and various resources, they capture the rainwater that infiltrates the soil to feed springs,

rivers, lakes and wetlands; produce and maintain fertile soils; capture carbon dioxide from the atmosphere thus reducing global warming potential; host indispensable pollinators for the fertilization of plants—responsible for much of the agricultural production and perpetuation of numerous wild plants—as well as agents that function as biological controls of agricultural pests; moreover, they offer us sites of recreation and inspiration. These are only some of the services natural ecosystems provide for us free of charge.

A nation integrates its heritage with several types of capital. The best known is economic capital (normally understood as "wealth"), which consists of the infrastructure (financial, industrial, agricultural, communications, generation and distribution of energy, etc.) of the country; there is also human capital, in terms of number, health conditions, educational level, professional capacity and social integration; and cognitive capital, represented by educational institutions and the ability to generate, synthesize and store new information. In recent decades, and as a result of the influence of both ecologists and leading economists such as Partha Dasgupta (2009) and several others (Jansson *et al*. 1994, Daily 1997, Prugh *et al*. 1999), the concept of natural capital has been adopted as a group of ecosystems, both natural and managed, which generate goods and services and are perpetuated either by themselves or by human management. Some authors include other natural products in this latter type of capital, such as hydrocarbons and minerals. In the context of this work we circumscribe the concept of natural capital exclusively to the ecosystems, the organisms they contain (plants, animals, fungi and microorganisms) and the services they provide.

Several economists believe that the concept of natural capital implies that the gross rate of saving of an economy is an inadequate measure of what that country is accumulating in reality, because it only measures investment in manufactured capital. This idea has convinced the World Bank to change the way it currently estimates the actual saving rate of a country, by taking into account the extraction and degradation of natural resources and ecological damage caused by human activity, although the present focus is solely on the damage caused by carbon dioxide emissions.

Traditionally, gross domestic product (GDP) is calculated on the basis of the economic flows of a country, and only reflects a fixed point in a long term trend; it is therefore unable to describe the future wellbeing of a country. Thus, GDP does not take into account the enormous value represented by nature, a value upon which our life depends. Those who live and depend most closely on the provision of these goods and services are those who suffer the effects of losses first, although eventually such losses affect all members of a nation and even the planet.

Through history, and with the experiences gained on a global scale, we should be clear that the answers to our problems related to conservation of the environment and natural resources will not be found through "technological fixes"; that is to say, by expecting that some new technology will repair our wrongdoings.

Experience tells us otherwise: such "technological fixes" have either failed to materialize when foreseen, delivered a minimal positive impact, or produced negative consequences which were the same or worse than the problems they were designed to address. Perhaps one exception has been the "Green Revolution", whose results led to a marked productivity increase, although this had little impact on the poorest of the poor; however, its environmental consequences were very harmful, in terms of soil and water pollution produced by the overuse of agrochemicals. Moreover, such systems are energy inefficient.

There is an almost total disconnection between economic thinking and the environmental aspects of economic activity. A detailed study (Kim *et al*. 2006) of the themes that economists have dealt centrally since 1970, did not find a single word related to environmental issues, such as environment, ecology, externalities, aquifers, ecosystems, climate, carrying capacity of the environment, forests, ecological footprint, etc. (see also Ehrlich 2008).

This is an area in which economists and ecologists must work together in common accord, firstly to understand the problems related to the environment and use of natural capital from their respective points of view and then to communicate to society, as broadly as possible, the consequences of their findings. This may contravene the *usual behaviour* of the scientific community, particularly the ecologists, but it is vital if we wish society to understand the severity and scope of the problems we face and the magnitude of the changes required to address them.

Ecosystems and their services constitute a capital of equal, or greater, importance than the financial and infrastructural capital of which a national economy is composed. However, with the exception of some countries, national accounts generally do not consider the deterioration of natural capital (beyond the consumption of hydrocarbon reserves and mining) nor its cost (such as externalities), in the calculation of produced wealth. According to INEGI (2009), the costs of natural resource depletion and environmental degradation were 8.8% of the Mexican GDP in 2006.

In the context of considering ecosystems as part of the natural capital, studies by several of the economists mentioned above, incorporating a vision which includes the value of natural capital, show that most countries actually have a negative economic growth when including the loss of natural capital as a cost of national economic activity. There is no doubt that this cost has an immediate or short term impact on the less privileged sections of society and, in the longer term, on the country itself.

4 *The transformation of natural ecosystems, to obtain goods and services for mankind, has brought benefits but also resulted in severe environmental costs; we still do not know how to value the balance between these costs and benefits.*

Any modification of a natural ecosystem, to satisfy human demand, involves a transaction. For example, a country can increase food production to meet the needs of its population through the conversion of natural ecosystems into agricultural systems; however, such conversions to obtain certain commodities or services will result in a reduction in the provision of other equally important services, such as water supply, regulation of flooding or silting and control of desertification. Policies that have precipitated such changes in natural ecosystems have never taken the long-term social cost into account. To a large extent, the study of the Millennium Ecosystem Assessment (MA 2005) has prompted interest from many countries to include an analysis of these transactional costs in public policy decisions. Such analyses are increasing on a daily basis and all statistics indicate that this trend will increase very significantly in the next four or five decades.

The MA results indicate that already there is clear evidence of a serious degradation of the planet's capacity to provide ecosystem services, including food production, in both terrestrial and marine systems at global, regional and local scales. The majority of the planet's ecological regions and global scale ecosystem services are in a clear process of degradation (MA 2005). For example, half of the tropical and temperate forests of the world have disappeared, as have more than a third of the world's mangroves. The marine situation is equally, or even more, severe: only 5% of stocks of the top organisms in the trophic chain, i.e. large predatory fish (billfish, marlin, etc.) has been saved from rapacious overfishing and physical changes and pollution in the marine environment. Similarly, 75% of the world's fisheries have been exhausted or are exploited to their maximum level. The amount of seabed that has been destroyed by trawling is now comparable to the entire deforested area of the Earth's surface.

5 *The argument that development is confronted with the sustainable use of resources and conservation of our natural capital, is delusory and irresponsible. It is a response to a lack of information or to the prevalence of individual or group interests over the public interest.*

For a long time in our country the prevailing argument has been that development is incompatible with the rational and sustainable management of our resources and the conservation of natural capital. Those who have contributed to this work consider that it is now time in our country to assume that this argument is both contradictory and wrong, and serves individual interests to the detriment of the majority of the population. Consequently, we must work in a context of sustained economic development, with permanent social benefits, bound by the environmental characteristics and capacity of ecosystems to support the human activity in question.

The natural capital of Mexico represents a great opportunity for development

and generation of benefits for the entire population. Historically speaking however, our policies of natural resource use have not favored the conservation or sustainable use of this capital, and have failed to improve the welfare of those who live in and of this natural capital, i.e. the rural population of the country.

We must understand that biological and cultural diversity is an inherent, consubstantial part of our country. Natural capital is a heritage that we must fully understand in order to value, utilize and conserve it appropriately for the benefit of all Mexicans, present and future. It is a capital that we cannot recover once we have destroyed. An awareness of that capital must be created in our country, above all by our own people: we cannot import it from other countries or regions. Ecosystems are not transportable from one place to another, and neither are the services they provide to us.

6 *The purpose of* Natural Capital of Mexico *has been to advance the level of knowledge about the natural heritage of the nation; progress from merely identifying challenges, to approaching and designing appropriate solutions, and to adopt a more proactive approach to problem solving.*

We have planned this work to contribute to the forging of a culture that promotes the fundamental importance of the biodiversity of our country and stimulates a greater appreciation for the tremendous value of ecosystem services provided to us by the varied nature of Mexico, while providing key factors to establish the decision to conserve our increasingly threatened natural capital. We wish to foster an understanding of the significance of transactions in ecosystem management, and to cause decisions that affect ecosystems to be taken with an increasingly multisectoral policy vision, rather than from the isolated standpoint of the environmental sector. With this approach, other sectors of government (agriculture, communications, trade, etc.) cannot overlook the environmental impact of decisions they make.

Among the main purposes of this work is the identification of options for the use of our biodiversity so as to harmonize the possibility of conservation and sustainable management of biological diversity, with tangible benefits for our population, especially those in ownership of ecosystems. We try to provide criteria to shape the environmental agenda in Mexico for the next ten years; a vision that is both useful and relevant to the Mexican Congress of the Union, staff in executive areas of the various levels of government, the academic community, civil organizations working on environmental issues and conservation of our resources, for civil society, political parties, the media, businessmen and industry, and ultimately the communities that have ownership of the country's natural capital. We have ensured that the *Natural Capital of Mexico* offers fundamental information that meets the needs of those who make decisions affecting our ecological heritage,

and to provide the best available information concerning the characteristics of our natural capital, the state of its conservation, the potential it represents if we adopt ecological criteria in its use. It also suggests scenarios of possible directions that this capital could take, depending on the various decisions and political actions of government or of society in general, in order to outline those options which would permit a resolution of the apparent dilemma between conservation and sustainable use, with an eye to present and future social welfare.

7 *This study has a background of previous assessments and analyses of Mexico's biodiversity, in accordance with the responsibilities of our country as a signatory of the Convention on Biological Diversity. It is also updated in the light of conceptual advances, new data, and the development of new technologies and methods of data analysis, with the broad participation of specialists.*

The first study of this nature was carried out and published ten years ago, utilizing bibliographic information sources of which the majority dated from prior to 1995. That study, coordinated by CONABIO, was a first attempt to provide those sectors involved in our biotic resources with a descriptive synopsis of the biodiversity of Mexico, and also enabled us to fulfill the commitments made in signing and ratifying the Convention on Biological Diversity (CBD). The information compiled has been since used as the basis for the design or evaluation of various environmental projects and in discussing and disseminating the importance of key issues related to the biodiversity of Mexico. It also constituted a national framework of reference for the states within Mexico which, with the encouragement and support of CONABIO, could produce their own individual reports. Around half of the states have done so to date.

It should be mentioned that, in relation to the first study, there has been a conceptual advance obvious from the title itself, *Natural Capital of Mexico*, which tries to capture the value of biodiversity from a social perspective. Another major difference has been both the number of participants in the work and the larger platform of available knowledge that has enabled this study. This was not only the result of a substantially increased quantity of data, but also of the development of new technologies and information analysis methods—particularly spatial—that has permitted a better understanding of many aspects related to the distribution of species, communities and ecosystems, and the relationships which exist between these elements.

It is also a reflection of the remarkable growth and diversification that the country has undergone in the last decades, not only in terms of human capabilities and resources, but also in the strength of governmental, academic and civilian institutions, and the greater maturity and collaborative abilities of their members.

This attempt to assess the current state of knowledge regarding the nature and conservation of the biodiversity of Mexico is unprecedented. It represents a work of compilation and summarization of available information concerning the components of biological diversity, several aspects related to stress factors that affect them, and the potential for sustainable management. Furthermore, we want to give special emphasis to the description and analysis of the services provided by ecosystems, and to relate the state of these services to the social welfare of the groups living directly in and from these ecosystems, and those in urban society, which receives these services in a less conscious manner. This approach has been inspired in large part by the global study known as the Millennium Ecosystem Assessment which was conducted over five years with the participation of more than 1360 scientists from 95 countries (MA 2005).

Structure of the work

This work is organized into five volumes, each comprising a variable number of chapters, in which we have attempted to make a scientific assessment of existing information. The first three volumes include 45 chapters, written by 648 authors and evaluated by 96 outside reviewers, and cover the following topics:

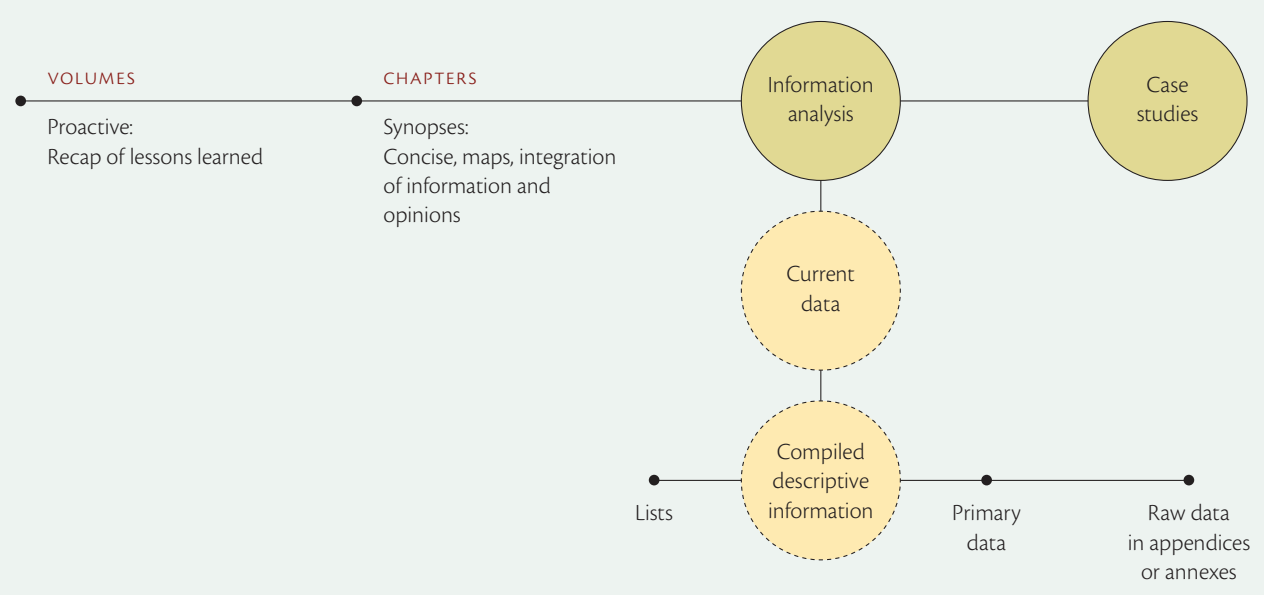
- *Volume I: Current knowledge of biodiversity*. To document the knowledge we currently have of our natural capital, central questions concerning what we know about biodiversity in Mexico are addressed. What knowledge do we have of the genetic diversity of wild and cultivated species? How many species of plants, animals and microorganisms have been described in our territory and how are they distributed? How many species have become extinct and which were endemic and therefore now extinct on the planet? What types of ecosystems exist in Mexico, how are they structured and what are some of their functions?
- *Volume II: State of conservation and trends of change*. We analyze the condition of the ecosystems and its biodiversity in different regions of Mexico by examining changing trends in the last five or six decades, the nature of these changes and the factors that have played a central role in them. We describe the measurable social costs or benefits of these changes. We examine the progress and limitations in the conservation of natural capital, and identify those salient aspects which will require close attention in the future. In particular, by addressing issues of biodiversity conservation in terms of loss of populations, cultivars, species and ecosystems of the country, and of the anthropogenic degradation of ecosystem functionality, we must understand that such biological deterioration translates into the loss of environmental services, on which social welfare is ultimately dependent.

- *Volume III: Public policy and prospects for sustainability.* Evaluates which have been the public policies and what have been their positive or negative effects on the rational management and conservation of our natural capital? How we can improve the country's ability to conduct evaluations of policies, conservation actions and sustainable management of Mexico's diversity and its benefits to society? We suggest which changes should be expanded and consolidated to achieve environmental sustainability in the use of biodiversity.
- *Volume IV: Human, institutional, and financial capacities*. To identify factors that have either facilitated or hindered us in reaching our current state of knowledge, evaluation, management and conservation of our natural capital, we assess what have been the institutional bases, human capital, levels of public and private financial support and other elements regulating progress or regress in relation to problems associated with the natural capital of Mexico. Furthermore, we pinpoint the major requirements for a healthy and sustained development of conservation efforts and sustainable management ecosystem in the near future.
- *Volume V: Future scenarios.* Possible scenarios of the biological diversity of Mexico are analyzed in the context of identifying the most probable changes to ecosystems and their services we will face in the future; the determinant factors in those changes, and the actions which can be taken to realize a more desirable situation for the country.

The structure of the volumes was conceptualized as shown in figure 1. Every measure has been taken to ensure that these chapters are comprised of the best

Figure 1

Schematic of the conceptualization of this work and its chapters.



and latest scientific and technical information, and that a representation of experts as balanced as possible was sought for each region and discipline. The authors responsible for each chapter have made an effort to ensure that there is always supporting documentation for the text, which enabled us to carry out an efficient monitoring system and ensures that the reader is aware of each information source in great detail. It is also hoped that such documentation can be reviewed in the future to develop further assessments of the natural capital of the country. In each chapter, we have also sought to identify existing gaps and omissions in the basic information, research, training, public policies, etc., which pertain to the subject.

Organization

This work was performed under the guidance of a general coordinator, giving vision to the study and its essential products, and a group of editors for each of the volumes. These named the authors responsible for the chapters, harmonized and integrated different experiences to fulfill the assessment and goals of each volume. The authors contributed with their experiences and knowledge to the various topics and were responsible for integrating the manuscripts on time and inviting a number of coauthors and authors of insets to enrich the content with their experience and to illustrate, in summary form, various processes or situations. Finally, a small secretariat was responsible for the coordination, organization and documentation of the process and for provision of support in all the necessary logistical tasks, such as meetings, and submissions for peer review and to the editor.

Peer revision

All chapters were reviewed by academic experts in the topic in question who had taken no part in their preparation. Final responsibility for each chapter was given to those named as responsible authors and coauthors. Comments and discrepancies, provided by the reviewers, were assessed one by one and, in the case of difference of opinion, discussed with the editors and resolved satisfactorily for both parties, in agreement with the authors responsible for each chapter or the editors of each volume. In the case of irreconcilable differences, a note was included describing the difference of opinion.

Additional information

In some of the volumes, data relating to the material of the chapters was presented in an attached compact disc. In the case of volume I, a disc was also in-

cluded which contained a species list of animals, plants, fungi and microorganisms that are known in Mexico to date, and which will also be available online at the CONABIO website so that interested specialists may consult, update, add and edit this list of Mexican species. This database is the first national effort of its type: it does not claim to be comprehensive or complete but rather aims to stimulate the interest of specialists of different groups in the world, for the improvement of our knowledge of Mexican biota. Included within the chapters are case studies or insets that show and discuss some successful or complementary experiences, or illustrate some of the topics in greater depth, discussed in the respective chapters. The first three volumes of the work—the chapter text and additional information of tables and primary data—are available for online consultation at the CONABIO website (*www.conabio.gob.mx*). The last two volumes will be available in 2010.

The following synopsis describes the main findings outlined in these volumes.

Diversity of native maize.

I

Mexico is one of the most biologically and culturally diverse countries. Much of the biodiversity is unique to our nation, and represents a serious responsibility we have towards the rest of the world. The relationships between biodiversity and cultures offer Mexico great opportunities for development. The corpus of knowledge and capabilities developed by the country, although it still has gaps and limitations, should be used as the basis for decision making regarding the use and conservation of the country's biodiversity.

The high biodiversity of Mexico is due to its complex physiography and its geological and climatic history. Mexican flora and fauna show geographic patterns which correlate to the characteristics of the physical environment and its geological history. Volume I includes a chapter on biodiversity in the relatively recent geological past, information which is very useful since it provides the context for the processes of climate change which we are experiencing today.

This great biological diversity of Mexico is reflected in the enormous variety of ecosystems and ecological processes that result from interrelationships between organisms and those between them and their physical environment. These processes form the basis of important environmental services, particularly in provisioning, regulating, cultural, and supporting services.

Mexico is not only noted for the high number of species it possesses, but also for the wealth of endemic species (confined to the county), and for the high genetic variability shown in many taxonomic groups as a result of natural and cultural evolution or diversification in the country. Pre-Hispanic Mesoamerican cultures domesticated a great number of species but also utilized many more, both wild and semi-cultivated, for food, therapeutics, textiles, religious activities, ornamental purposes and construction.

Together with Indonesia, Mexico stands out in the world for the close correlation between its biological and cultural diversity. It ranks first in the Americas, and fifth worldwide, for the number of languages in existence (291 living languages in the country). Throughout Mexico, the distribution of linguistic variation corresponds closely with the areas of greatest biodiversity.

Ours is a country privileged by the exceptional biological diversity of its territory, expressed in the multiplicity of ecosystems and the wide genetic variability of their numerous species, which is particularly evident in the case of cultivated plants.

As discussed in volume I, it is estimated that hundreds of thousands of species occur in the Mexican territory. These show a wide genetic variation which is particularly evident in the case of cultivated species.

To date, about 1.8 million species of animals, plants and microorganisms are known in the world, out of a conservatively estimated potential total of more than 10 million species. That is to say, more than 80% of the total possible species remain unknown to us, but at the same time we have a clear picture of the magnitude of the richness of life and its distribution on Earth. We also have sufficient knowledge to determine that Mexico is one of the four countries with the largest numbers of plant and animal species worldwide, and is therefore among those countries, known as "megadiverse", which contain between 60 and 70 percent of the known diversity of the planet. The proportion of species present in our country to the recognized world total is considerably higher (about 10 to 12%) than the proportion of land surface that Mexico occupies in the global total (1.4%) (see chapter 11 of volume I).

The best known of the species groups is that of the terrestrial vertebrates. Figures 2a and b comparatively illustrate the total and endemic species richness of vertebrates. With regard to mammals, 535 species live in Mexico, of which 488 are

Figure 2a

The five countries with the greatest diversity of vertebrates (source: CONABIO 2006).

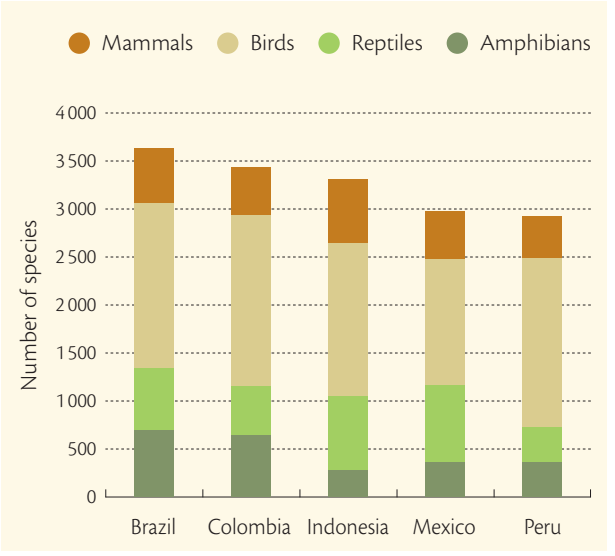
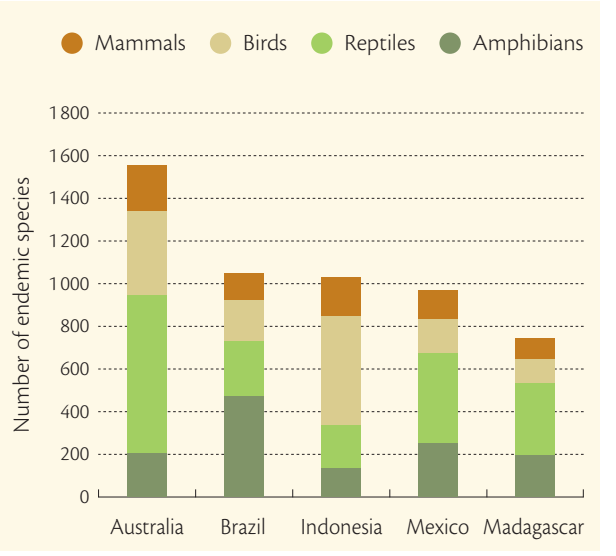


Figure 2b

The five countries with the greatest diversity of endemic vertebrates (source: CONABIO 2006).



terrestrial and 47 are marine (Ramírez Pulido *et al*. 2005, 2008). Our country is second only to Indonesia and Brazil, which have total numbers of 667 and 578 species, respectively. Mexico has the greatest number of species of marine mammals.

With a total land area 3.5 times greater than that of Mexico, Australia has 880 species of reptiles, while in our territory 804 species have been described so far: globally, Mexico ranks second in number of species of this group (Flores-Villela and Canseco-Márquez 2004).

Mexico, with coastlines on the Pacific and Atlantic Oceans and the Caribbean Sea, is also the only country with a sea (the Gulf of California or Sea of Cortés) entirely encompassed within its own territory. Mexican territorial waters are home to many ecosystems, and species with the most varied forms of life. For example, 2 184 species of marine fish have been described, a figure exceeded only by the Asian Pacific region, formed by Indonesia, the Philippines, Australia and part of Papua New Guinea, which constitutes a much larger area. Table 1 summarizes information regarding the vertebrates present in Mexico, including the number of these species described, those estimated to exist in reality, the number endemic to our country and the known total for each group in the world (Fig. 2).

With regard to the largest group of animals, the insects, 47 853 species have been described in Mexico to date, but there are estimated to be around one hundred thousand species.

Mexico is among the five countries with the highest number of vascular plant species: more than 25 000 have been described to date, from a total estimated to be between 27 000 and 30 000; a high proportion of which are endemic to the country (Figs. 3a and b).

Figure 4 comparatively illustrates the species richness of fungi, plants and animals in Mexico and in the world.

For the first time in one reference source—and one data base—information has been compiled about the species of animals, plants and microorganisms which have been described in our country. The information is presented in two ways: on an attached interactive compact disc and online at the CONABIO website (*www.conabio.gob.mx*), so that specialists in different groups of organisms worldwide can review and correct this information or increase it with informa-

Table 1 Species of vertebrates described in, estimated in, and endemic to Mexico, and the total described worldwide (chapter 11, Vol. I)

	Described in Mexico	Estimated in Mexico	Endemic to Mexico	Described worldwide
Fish	2 692	2 729	271	27 977
Amphibians	361	371	174	4 780
Reptiles	804	812	368	8 238
Birds	1 096	1 167	125	9 721
Mammals	535	600	161	4 381

Figure 3a

The five countries with greatest diversity of vascular plants (source: CONABIO 2006).

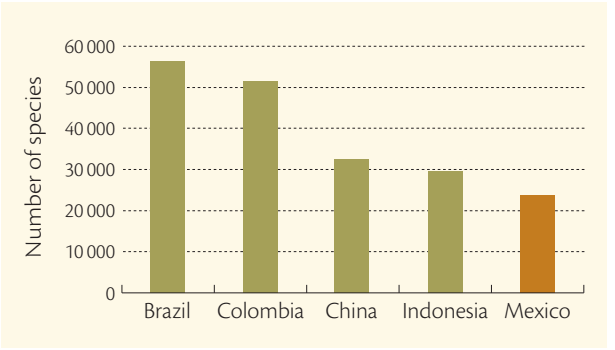


Figure 3b

The five countries with greatest diversity of endemic vascular plants (source: CONABIO 2006).

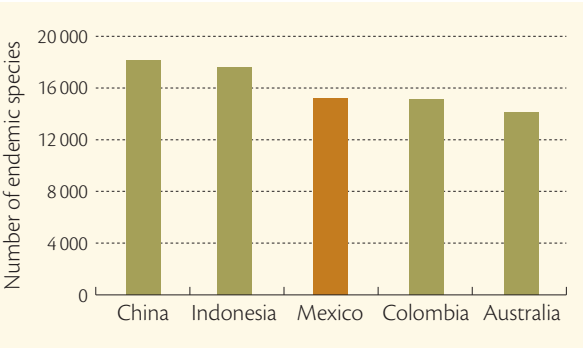
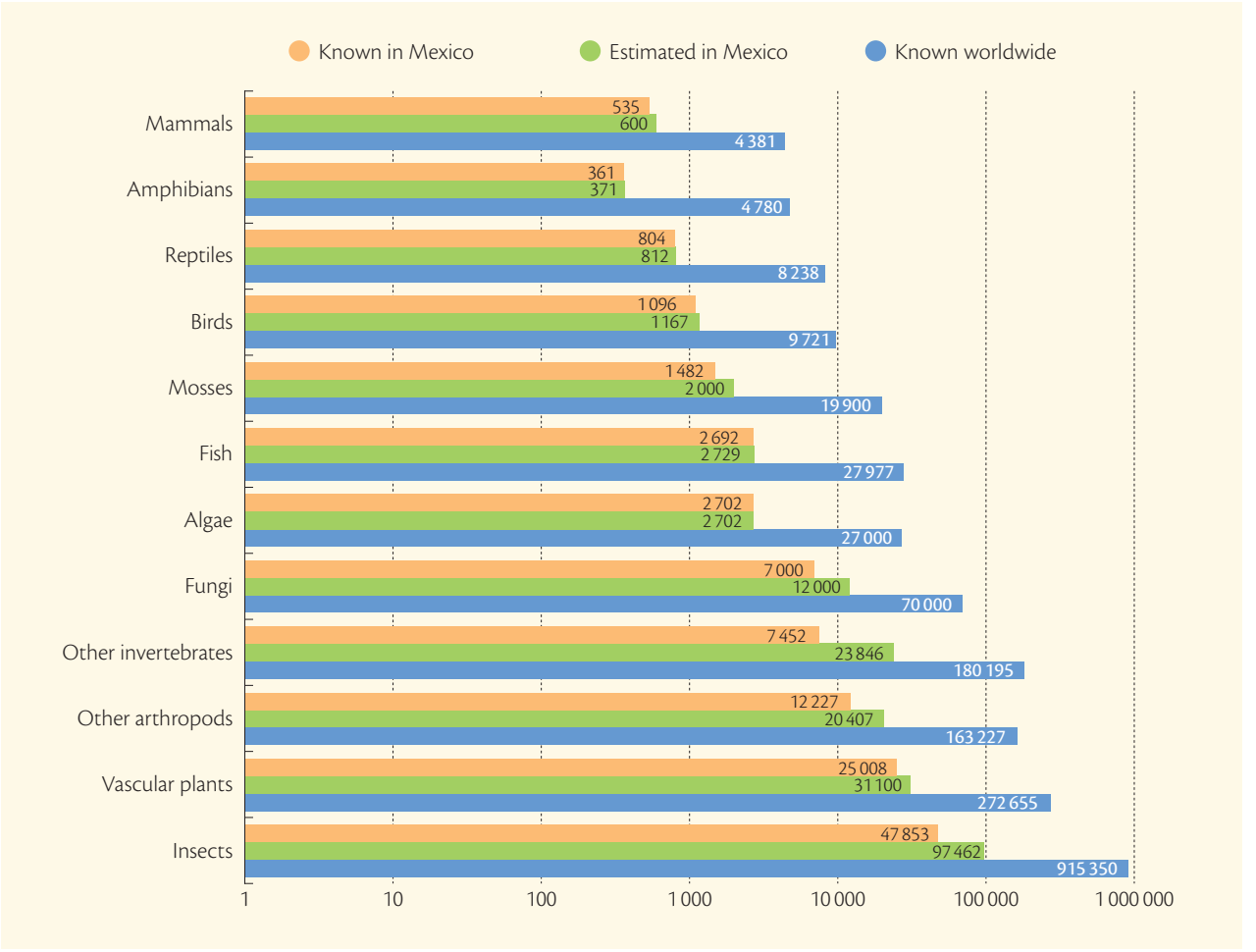


Figure 4

Diversity of species of fungi, plants, and animals in Mexico and worldwide (CONABIO 2006; chapter 11, Vol. I).



tion unknown at the time of producing this work. This input will give us up to date knowledge of the species which have been described in Mexico as well as the validation of experts in these different groups.

9 *Much of the biodiversity of Mexico is unique to our country and this gives us a great responsibility at the regional and global levels.*

A special aspect of the exceptional biodiversity of Mexico is the high proportion of species that exist exclusively in our country (endemic species), which places even more value on it. In this regard, Mexico also stands out when compared with other megadiverse countries (Figs. 2 and 3).

For example, around 15 000 endemic plant species (between 50 and 60% of the known species in Mexico so far) have evolved in our territory. This means that potentially more than half of our flora cannot be found anywhere else in the world. If one of these species becomes extinct in Mexico, it disappears from the world.

For these reasons, endemic species are particularly important in relation to biological diversity and therefore become a priority for conservation policies. It should be made clear that, once lost, we cannot "import" these species that make up our ecosystems from any other location.

Among vertebrates, the reptiles and amphibians are the groups with the highest proportion of endemic species, with 57 and 65 percent, respectively. Mammals (terrestrial and marine) and freshwater fish also display high degrees of endemism, which are equivalent to 32% in both cases, thus we have the responsibility to better know, use and conserve this heritage.

10 *Due to the great ecological variability, the biodiversity of Mexico is distributed heterogeneously, which has important implications for conservation.*

In common with many parts of the world, Mexico generally has more species in the tropics than in temperate zones. However, the extraordinary combination of factors that exists in Mexico, influences evolutionary processes and causes extremely complex spatial patterns of biodiversity. Knowledge of the distribution areas of species, and their geographical arrangement, shows us that the biodiversity of Mexico is unevenly distributed. In general, there are more species per unit area to the south, in the humid tropics. For example, the latitudinal concentration pattern of terrestrial vertebrates and vascular plant species is well known, although there are many exceptions due to the complex biogeographic history of the country. In Mexico, several particularly rich groups exist in the deserts, such as the cacti (Dávila *et al*. 2002), groups of animals with biogeographic patterns determined by

the mountains (Halffter 1987, 2003) and a huge number of endemic and micro-endemic species which do not necessarily correlate with patterns observed between taxonomic groups.

Endemic species distribution has well defined patterns in Mexican territory: although it varies for different groups, a lower number of endemic species is found in the humid tropics, a higher proportion are found in sub-humid tropical regions and a very high proportion found in arid and semiarid regions. Distribution patterns of species richness and concentrations of endemic species for different groups do not coincide (Fig. 5). This all implies that each region of the country has a distinct biodiversity, with profound consequences for its conservation, use and management. The biodiversity of the whole country cannot be represented within a few areas and we cannot establish uniform policies of conservation and use, which is one reason why the national agenda should consider regional approaches and policies that are more appropriate to the complex heterogeneous distribution of the country's biodiversity.

Spatial patterns of diversity show that no single group can serve to identify the sites of greatest biodiversity, and describing these patterns is a fundamental aspect for defining the most appropriate instruments for conservation. For example, in the case of groups such as birds, and in regions that can be considered conservation priorities for the exceptional biodiversity they contain (*hotspots*, i.e. areas with high concentrations of endemic species which are in danger of extinction or at risk of disappearing due to human pressure), biosphere reserves can be an appropriate management option as they often include large areas with established land use zoning systems (Halffter 1984, 1988). Mexico has been a pioneer in establishing such reserves, but it may now be time to seriously evaluate their real role in conservation. Furthermore, for groups such as amphibians and reptiles, and in regions of high heterogeneity, such as the Neovolcanic Belt, it would be more appropriate to consider the legal and practical implementation strategies of new models of conservation, such as biological corridors or the strong commitment to support sustainable and low impact on ecosystems management, outside the protected areas.

11 *There is an enormous diversity of terrestrial ecosystems in the country. Quantitative details regarding the environmental services they provide are scarce, but there is no doubt of their economic importance.*

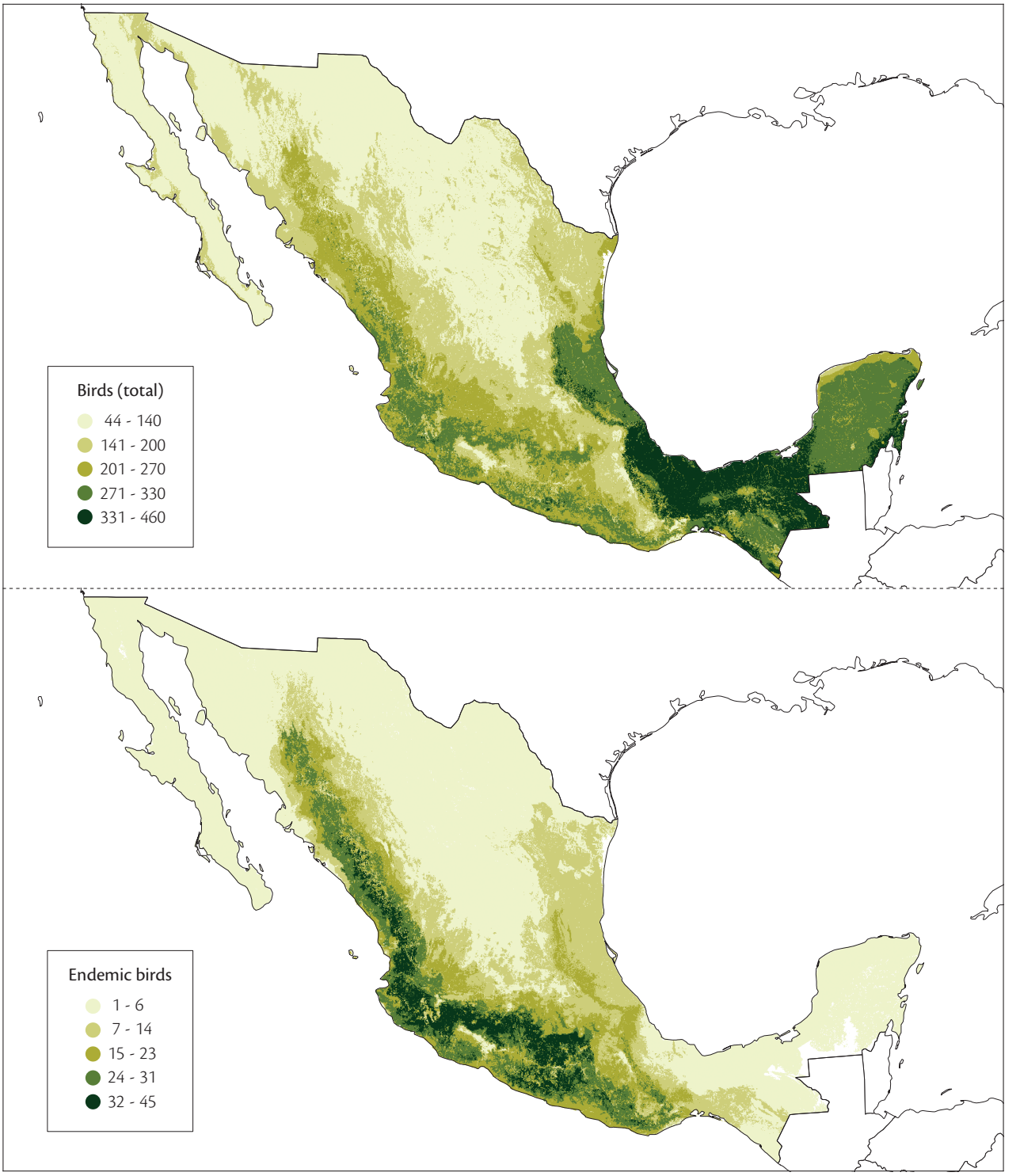
The great ecological variability and complex topography and geology of our land, with its distinct climates and microclimates, produce a myriad of habitats. All these factors are conducive to the expression of biodiversity in many different terrestrial ecosystems.

In the northern and central part of Mexico arid and semiarid zones are present,

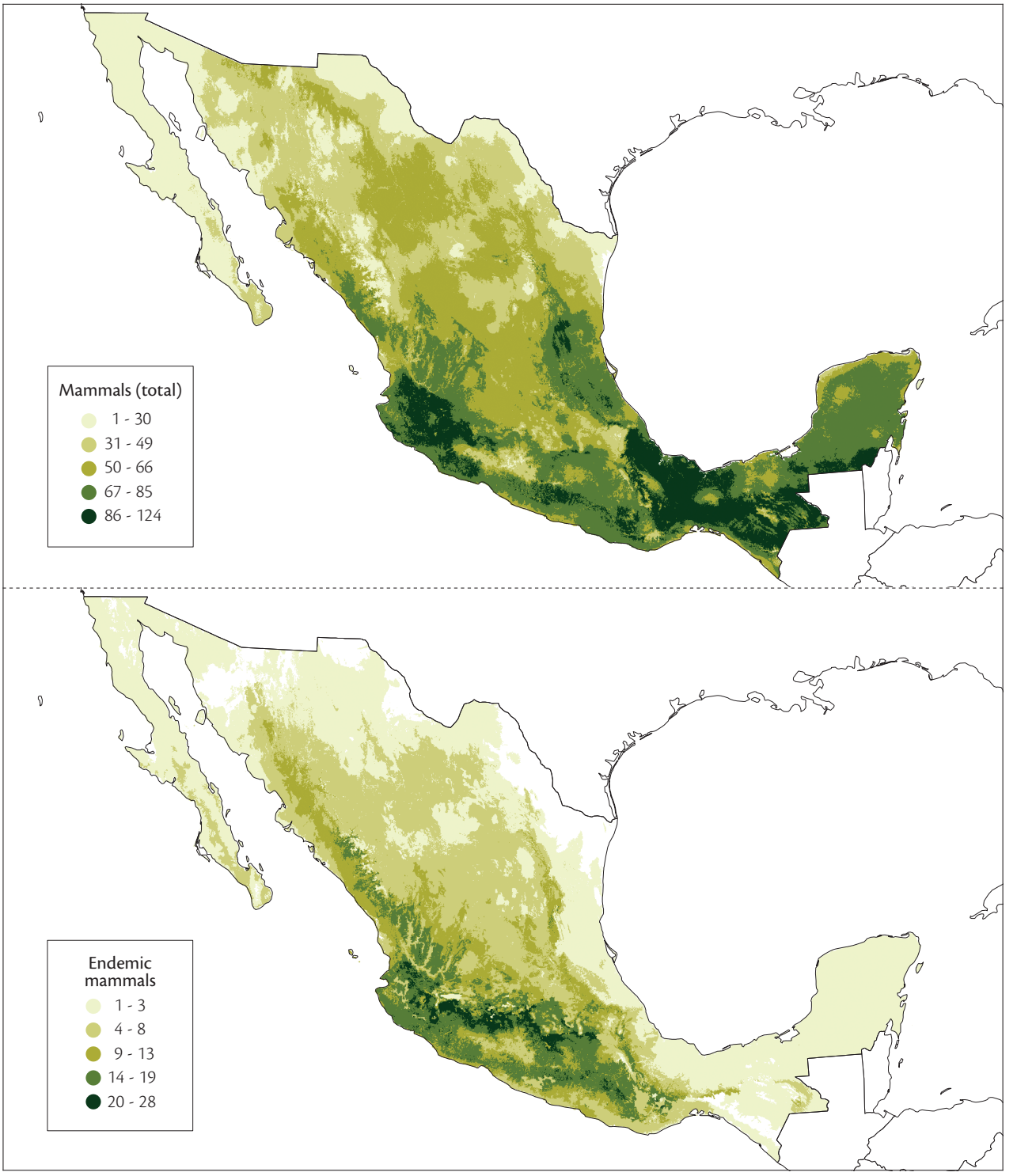
Figure 5 [*this page and overleaf*]

Non-concurrence of distribution patterns of species richness and of concentration of endemic species for (*a*) birds and (*b*) mammals (chapter 12, Vol. I).

5a Birds



5b Mammals


Mammals (total)
1 - 30
31 - 49
50 - 66
67 - 85
86 - 124
Endemic mammals
1 - 3
4 - 8
9 - 13
14 - 19
20 - 28

characterized by xerophytic shrubs, grasslands and thorny woodlands; in the Pacific coastal dry plains, the central plains of the Gulf of Mexico and northwestern Yucatán, occur the dry and semi-dry tropical forests; in the most humid zones, below 900 meters above sea level, are located the tropical evergreen forests, with the cloud forests at higher altitudes; finally, in the mountains one finds the coniferous and oak forests.

Recently, ecoregions have been recognized as areas which contain a geographically distinct assembly of natural communities that share the vast majority of their species and ecological dynamics, as well as similar environmental conditions. In the case of Mexico, we have a detailed 1 : 1 000 000 scale map which defines 96 terrestrial (continental) ecoregions, (INEGI-CONABIO-INE 2007), which has proved to be a very useful indicator in conservation planning.

Understanding the basic ecological processes that maintain ecosystem function is an essential task; however, we do not yet have maps at the regional and national scale.

The generation of this information, which will facilitate the conservation and utilization of ecosystem services, is a forthcoming task. We require a clear understanding of how basic ecological processes operate in order to plan and implement better programs of sustainable ecosystem management, which would include optimal management of the ecological services on which economic and social development depends.

12 *Marine biodiversity in Mexico, which is exceptionally high and relatively less well-known than the terrestrial, represents a potential natural resource which continues to be badly squandered.*

Mexico's geographical location, between the oceanic influences of the central-western Atlantic and central-eastern Pacific, accounts largely for its massive diversity of marine species and ecosystems. In terms of coastline and marine extent, Mexico is the twelfth best-endowed country in the world which, in common with other countries, represents not only great opportunities, but also challenges in the development of strategies and public policies for the sustainable use of marine resources.

A great diversity of ecosystems also exists in the marine environment; resulting from features such as continental slopes, abyssal plains, oceanic islands, trenches and submerged mountain ranges. In order to characterize the seafloor in terms of depth and topography, Mexican waters include 28 ecoregions (Fig. 6).

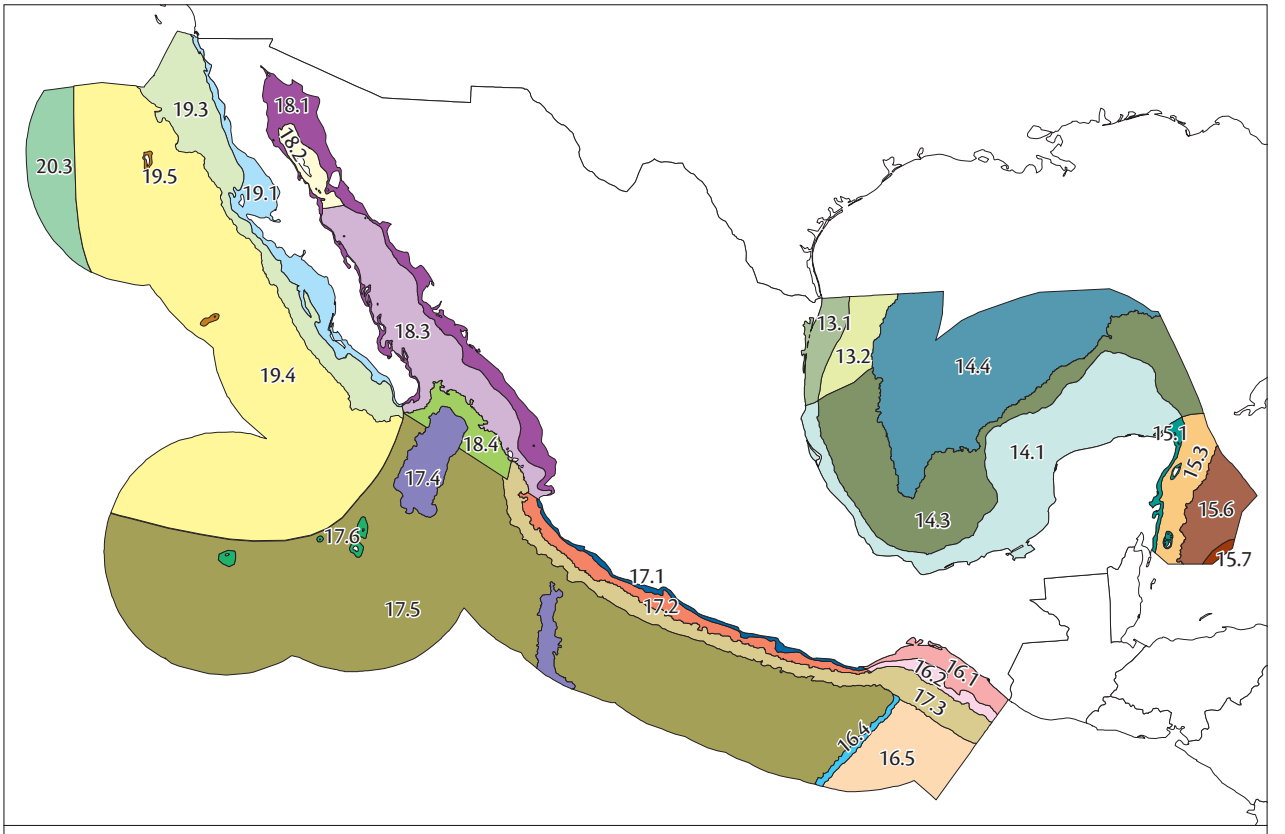
Integrated oceanographic research of marine ecosystems is very recent. The necessary investments to provide the country with the infrastructure needed (institutions, equipment, research vessels) to learn more about our marine resources and training of human resources, have progressed very slowly. Added to

this, the poor connection between the academic, private and governmental sectors in the fisheries area has hampered the organization of an agenda for the understanding and management of marine and coastal resources in Mexico.

With the exception of those species of economic interest, we have a serious lack of knowledge regarding the marine biodiversity of all the groups, of both deep and shallow waters. We are also largely ignorant of the environmental and

Figure 6

Level II marine ecoregions of Mexico (chapter 5, Vol. I).



13.1 Northern Gulf of Mexico Shelf
13.2 Northern Gulf of Mexico Slope
14.1 Southern Gulf of Mexico Shelf
14.3 Southern Gulf of Mexico Slope
14.4 Gulf of Mexico Basin
15.1 Mesoamerican Caribbean Shelf
15.3 Mesoamerican Caribbean Slope
15.6 Yucatán Basin
15.7 Caribbean Caiman Mountain Range
16.1 Tehuantepec Gulf Shelf
16.2 Tehuantepecan Slope
16.4 Tehuantepec Ridge
16.5 Guatemala Basin
17.1 Mexican Pacific Transition Shelf
17.2 Mexican Pacific Transition Slope
17.3 Mesoamerican Trench
17.4 East Pacific Rise
17.5 Mexican Pacific Transition Plain and Seamounts
17.6 Revillagigedo Oceanic Archipelago
18.1 Cortezian Shelf
18.2 Midriff Islands Straits
18.3 Gulf of California Slope and Basins
18.4 Gulf of California Plains and Seamounts
19.1 San Diegan Shelf
19.3 Baja California Borderlands
19.4 Southern Californian Plains and Seamounts
19.5 Southern Californian Oceanic Islands
20.3 Montereyan Pacific Transition Plain and Seamounts

socioeconomic consequences of changes in the services which marine ecosystems provide. A long term plan for oceanic research is required to maximize the opportunities for exploration, collection, management and analysis of oceanic data, in order to provide decision makers (individual fishermen, the fishing industry and governments) with the scientifically sound information necessary to carry out the sustainable use and proper conservation of our seas.

The seas and coastal areas of Mexico are one of the pillars of national development. Unfortunately, environmental degradation continues to increase daily, with a consequent loss of natural marine biodiversity habitats and many socioeconomic resources. Mexico is currently one of the countries with the most fragile marine ecosystems, which are highly vulnerable to the impacts of natural phenomena and those of anthropogenic origin, including climate change.

13 *Coastal, island and inland aquatic ecosystems, though apparently modest in size, are crucial for the maintenance of a biota of economic and biological significance. Much of the human economic activity, of marginalized coastal populations, depends on the condition of these ecosystems.*

Coastal ecosystems are a complex of lagoons, estuaries and other formations. They reflect the dynamic relationships between continental and marine areas, and are of great importance both economically and socially and for the protection of our coastlines. Since the coastlines are exposed to different ocean systems, the variability of these ecosystems is remarkable. Processes occuring in coastal areas are crucial to maintain populations of most fish species of economic importance to coastal fisheries (practiced by individual fishermen, largely for subsistence) and industrialized fishing. Mangrove areas are especially critical in this process (Fig. 7).

The complex coastal zone problems, with all its factors, has thus far been addressed by the government in a non-integrated manner, with isolated, sector-based approaches which have led to sporadic and often contradictory plans and programs. Moreover, the existing scientific information has also been produced in a haphazard manner, driven by the occasional and disjointed demand for information of various government bodies.

Coastal areas are of strategic importance, in terms of economic development and national security, and are host to a large diversity of activities that often involve conflicts over the use and ownership of resources such as soil, water and landscape.

Among the major issues pertaining to the coastal areas of Mexico are, firstly, the loss of intertidal habitat, dunes or cliffs, due to deforestation, land use change for urban, harbor and tourism development, mining or extraction of construction

Figure 7

Map of mangrove ecosystems (CONABIO 2008a).

filler materials; and secondly, the removal or reduction of wetlands due to land use changes, or siltation or sedimentation, caused by the upstream river channel alteration.

An integrated plan of study, knowledge and management based on environmental criteria must be implemented in these areas to lead to the sustainable use and protection of coastal systems and to benefit those populations living within them. That plan should include multidisciplinary participation (including natural and social sciences) and must be based on planning actions which cut across different levels of government. In addition to consistency of information generated by such an integrated plan, management of this type represents an action of national security and could help to protect our territory, and the populations which live in these vulnerable areas, from the effects of extreme climatic events. Such events are occurring with increasing frequency and severity, as a result of the global climate change we are already experiencing.

The lack of instances of coastal resource management, together with the ir-

regular availability of information, represent an irretrievable loss of opportunity for socioeconomic development of these areas and for those who depend on their successful function, such as the majority of the fisheries. Tourism development, carried out without the adoption of long-term planning based on the environmental characteristics distinctive to these system, that ensures its sustainability and provision of social benefits, currently represents one of the most serious threats to these regions.

Coral reefs are particularly biodiverse formations that occur in the vicinity of coastal regions. They represent the most biologically rich marine ecosystem, and have a great influence on the reproduction and protection of many important marine fish species. Although different formations of coral are found in both the Pacific and Atlantic coasts, the most important formation is the Mesoamerican Reef system located in the Caribbean Sea and shared between Mexico, Belize and Guatemala. This formation is the second largest barrier reef in the world.

Our country has more than 3 000 geomorphological units including keys, islands, reefs, islets, shoals and bars (INEGI 1994) in the waters surrounding Mexico. In the Pacific, most of the islands are located in the northwestern region that includes the Gulf of California and the west coast of the Californian Peninsula; in this region, there are about 900 islands and islets. These have a large variability of size, topography and biodiversity and, despite their modest size, are very important due to the presence of endemic species, particularly birds, of which we have already lost a substantial number (see chapter 10 of volume I) over the past 60 years, due to the influence of invasive species introduced by fishermen and visitors. Groups of endemic species such as cacti and reptiles are also important in the islands and islets. The islands are the ecosystems with the largest number of extinctions, of which most species were endemic. For example, the islands of the northwest region are areas essential for the reproduction of more than 30 species of eastern Pacific seabirds, two species of sea turtles and four species of seals. They are also the habitat of at least 218 endemic species and subspecies of plants and animals, including 81 reptiles, 45 land birds and 92 mammals. Many of these species are currently threatened or in danger of extinction.

Although the continental aquatic systems (lakes and rivers), are of relatively little significance in terms of size they are invaluable because they contain an important amount of endemic fauna, especially fish species, and are of great importance to the hydrological cycle in different regions of the country. These are systems that have been severely impacted by human activities; from the desiccation of bodies of water by human appropriation for urban and agricultural purposes, and their serious reduction in volume by the disruption of ecosystems in rainwater catchment areas, to overexploitation, chemical pollution and the introduction of exotic species which have caused the extinction of many native and endemic species (see chapters 10 of volume I and 6 of volume II).

14 *Judging from the species of which we have information, the genetic diversity of Mexican biota is enormous. The industrial importance of this is truly strategic for Mexico.*

The genetic diversity of species governs their ability to adapt to changes, including those caused by human disturbance, in the environment in which they are found. It is also the basis of their evolutionary processes. Studies of population genetics may reveal important aspects about species: the evolutionary history of a group, the mechanisms or factors that may have an influence on the loss of genetic diversity and information concerning their geographical relations, and inter-population connectivity are all aspects of great utility to conservation programs. Knowledge about genetic structure and diversity of populations has important applications, not only in the conservation of species and ecosystems and in restoration projects, but also in public health, agriculture, livestock production, fisheries and forestry sustainability and productivity, the domestication of organisms, and biomedicine (table 2).

Despite the enormity of the task of studying thousands of species of ecological, economic and biological importance to the country, the current level of knowledge regarding the genetic variation present in Mexico has increased markedly, especially in the last fifteen years. This knowledge is, however, still very limited when compared with total species richness. This study found that information from genetic variation research was available for only 45 species, listed in NOM-059-SEMARNAT-2001, from a total of 2 583 (see chapter 15 of volume I). Until now, most studies of genetic diversity in Mexican species have focused on a handful of organisms of economic interest, mostly plants. *Natural Capital of Mexico* introduces, for the first time, an approach towards a fuller knowledge of the ge-

Table 2 Mexican species for which studies of genetic diversity are cited in this work (chapter 15, Vol. I).

		Studied species	Described species
Microorganisms		11	?
Fungi		2	6 000
Plants		97	23 522
Animals	Platyhelminthes	1	550
	Insects	27	47 853
	Crustaceans	3	5 387
	Fish	16	2 692
	Reptiles	9	804
	Birds	5	1 096
	Mammals	36	535

netic diversity of our species. A simple increase in the number of individuals cannot guarantee the health of populations if the genetic diversity of these populations does not increase accordingly.

Strategies of conservation of the genetic diversity of domesticated species may not be the same as those applied to wild species; they should be based on the management of crop species, conservation of the processes of domestication used by indigenous groups, and *ex situ* conservation policy.

A significant number of the studies reviewed underline the fact that the greatest genetic variability is found in the centers of origin of species, as is found in the case of maize, cotton and nitrogen-fixing microorganisms such as *Rhizobium*.

The available information reinforces the idea that the ecological variability of Mexico is reflected in the genetic heterogeneity of its species. This implies that policies of conservation and restoration should display a population-spatial representativeness for the species in question, and that we must link such genetic information with analyses of those regions defined as priorities for conservation.

Fragmentation of ecosystems has harmful effects on the structure and genetic variability of populations, but further studies are needed to better assess the consequences of habitat loss, particularly in species with small populations.

There are contributions in the study even for the field of public health. In the case of *Trypanosoma cruzi* (which causes Chagas disease) and other pathogens, wide genetic heterogeneity can be found; public health policies should therefore be adopted based on diverse strategies focused on these different genetic lineages simultaneously. These results are also of interest to agroforestry pest management.

An online database, maintained by a network of researchers and specialists in the area, would have a significant impact on the verification and dissemination of genetic information of Mexican species and could help to stimulate the training of new researchers in the area.

15 *The diversity of the genetic resources contained in our crops constitutes both a national and global heritage. It has, besides its intrinsic biological and cultural value, a potentially very important economic value that we must make better use of.*

As stated earlier, Mexico is an important center of domestication and diversification of many crops, some of them of global importance. Cultivated species in Mexico have many wild relatives that can, or already do, amplify the high genetic diversity of cultivars of many species consumed worldwide, and therefore these species represent a resource of great importance in terms of food security.

The results of molecular analyses show a much greater genetic diversity in our cultivars than that which arises from traditional agromorphological analyses, since these can reveal gradients of variation, rather than identifying discrete groups.

Genetic diversity is not just the result of environmental and biological factors, but also, importantly, of processes of domestication and diversification by human management. However, we do not have systematic methods to track changes that have occurred in the past—and continue to this day—in the diversity brought about by the country's small farmers, who are mostly indigenous and peasants, in the context of their fields, plots, orchards and plantations. In contrast to these sources of diversification, there is a consensus that the genetic diversity of these resources has decreased and the trend suggests it will continue to decline. Some of the reasons for this are the demographic and cultural changes in rural and urban populations, and the type of support policies which have been applied in the rural sector.

The *ex situ* conservation of the genetic diversity of cultivated plants is problematic in terms of funding and demands a strong institutional commitment, despite the existence of government support programs. On the other hand, the *in situ* conservation of wild relatives of cultivars is relatively incipient and it is clear that these wild relatives are under serious threat by deforestation and changes in land use. In fact, conservation on small farms or agricultural fields continues in the agricultural systems of peasant farmers, but receives no formal support. On the contrary, this practice faces many adverse factors, including the growing tendency to replace cultivars with synthetic varieties and the ecological simplification of the fields under cultivation.

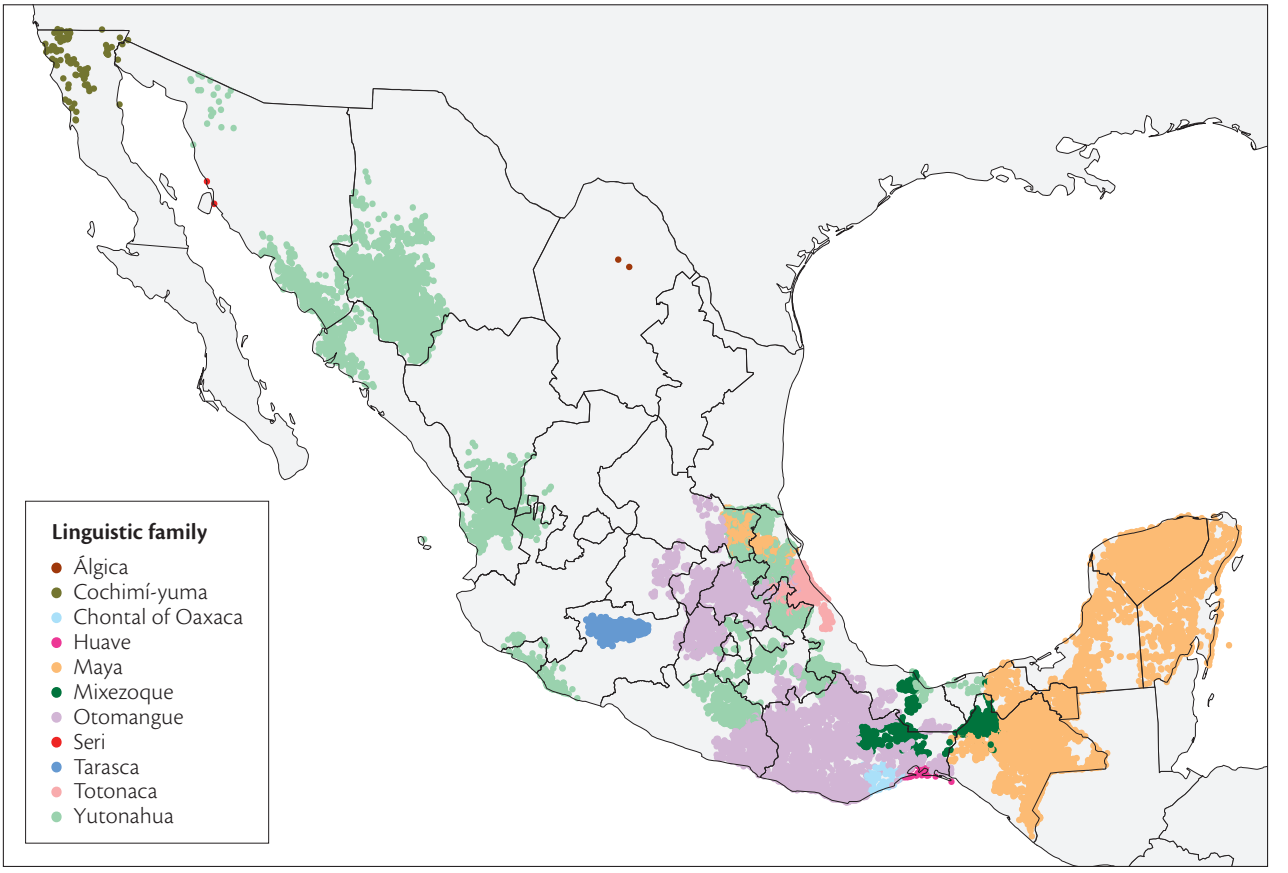
This diagnosis makes it clear that the future of this agrodiversity is linked to the future of the rural population and to the values of culture and identity it continues to represent. An explicit national policy is required, with concrete funding, defining clearly a number of interrelated *in situ* and *ex situ* conservation actions, for the diversity of native cultivated species and their wild relatives.

16 *The biological diversity of Mexico is accompanied by a great cultural diversity. There are very close and important relationships between them. The result is that Mexico is one of the most important centers of origin of agriculture and of domesticated vegetable species essential to the economy and to human life.*

Like any region with ancient indigenous cultures, knowledge of the different components of biological diversity has been developed in Mexico over millennia. There are documentary sources that provide us a glimpse of the wealth of knowledge acquired by the aboriginal ancestors, but still today a large and dynamic flow of knowledge survives and is maintained and developed in marginal farming communities and rural areas of the country. This accumulation of knowledge has sometimes been ignored, at other times excluded, and has only on occasion been accepted and recognized by that other great source of knowledge that is western

Figure 8

Linguistic families of Mexico (chapter 16, Vol. I).



science, which has been key to the study of the unique biological richness of Mexico.

The rich cultural mosaic within Mexico is evident by the existence of the many indigenous languages that are spoken in the country. Depending on the criteria of classification, these range in number from 59 to 291 in 68 groups within the 11 indigenous language families represented (Fig. 8). If we consider 291 separate languages, Mexico has 30.2 and 4.2% of the total continental and global numbers, respectively. However, a total of 364 language variants have been recognized in Mexico and should be considered as languages (see chapter 16 of volume I). This places Mexico among the 10 countries with the greatest linguistic—and hence cultural—diversity in the world.

The cultures that exist and have existed in our country have developed a close relationship with the biodiversity in their environment, both in their worldview and in the way they have exploited available natural resources. It is estimated that there are at least 118 species of economically important plants that were completely or partially domesticated by pre-Hispanic farmers, making Mesoamerican

Mexico one of the major world centers of plant domestication (table 3). Over 15% of plant species consumed worldwide as food, have their origins in Mexico.

From the sixteenth century, an exchange of species began generating a flow of materials which brought wealth not only to the other continents but also to our own, with species that interbred and diversified in our territory, thanks largely to the innovative capacity of indigenous groups. Several species associated with the

Table 3 Selection of plants which originated or were domesticated in the Mexican territory (chapter 18, Vol. I)

Main use	Common name	Species	Origin
Green manure	Leadtree	*Leucaena esculenta, L. leucocephala*	Mesoamerica
Food	Avocado	*Persea americana*	Mesoamerica
	Cacao	*Theobroma cacao*	Mesoamerica
	Pumpkin	*Cucurbita pepo, C. moschata*	Mesoamerica, Tropical America, North America
	Sapodilla	*Manilkara zapota*	Mesoamerica
	Bean	*Phaseolus vulgaris*	Mesoamerica
	Guava	*Psidium guajava*	Mesoamerica, Northern South America
	Jicama	*Pachyrrhizus erosus*	Mesoamerica
	Tomato	*Lycopersicon esculentum*	Mesoamerica, Northern South America
	Maize	*Zea mays*	Mesoamerica
	Tejocote	*Crataegus mexicana, C. pubescens*	Mesoamerica
	Tomatillo	*Physalis ixocarpa*	Mesoamerica
	Prickly pear / Nopal	*Opuntia albicarpa, O. ficus-indica, O. megacantha*	Mesoamerica
Drink	Maguey cenizo, maguey del cerro	*Agave asperrima*	Mesoamerica
	Maguey mezcalero, maguey espadín	*Agave angustifolia*	Mesoamerica, Northern Mexico
	Maguey mezcalero, maguey tobalá	*Agave potatorum*	Mesoamerica
	Maguey pulquero, ixtle	*Agave salmiana*	Mesoamerica, Northern Mexico
	Maguey tequilero, maguey azul, agave azul	*Agave tequilana*	Mesoamerica
Condiment	Achiote	*Bixa orellana*	Mesoamerica
	Chili peppers	*Capsicum annuum*	Mesoamerica
	Vanilla	*Vanilla planifolia*	Mesoamerica
Stimulant	Tobacco	*Nicotiana rustica*	Mesoamerica
Fiber	Cotton	*Gossypium hirsutum*	Mesoamerica
	Henequen	*Agave fourcroydes*	Mesoamerica
Rubber	Chicle, chicozapote	*Manilkara zapota*	Mesoamerica
Waxes	Candelilla	*Euphorbia antisyphilitica*	Northern Mexico, Southern USA
Ornamental	Cempasúchil, flower of the dead	*Tagetes erecta*	Mesoamerica, North America, South America
	Poinsettia	*Euphorbia pulcherrima*	Mesoamerica
Dye	Indigo	*Indigofera suffruticosa*	Tropical America

Sources: Dressler (1953); Martínez (1979); Hernández Xolocotzi (1985); Germplasm Resources Information Network (2006); Perales and Aguirre (2008).

ancient people not only remain in use today, but constitute more than half of the diet of the country. Others may have lapsed into disuse, but still retain potential for development.

Many other non-domesticated native species that have medicinal, ornamental or forestry utility, constitute an economic potential for the future. In contrast with the wide diversity of domesticated plants, only two animal species were subjected to some degree of domestication: the turkey, of American origin, and the dog, introduced from Asia by the first settlers of America. Most native animals are subject to hunting, while some species, such as Meliponid bees and cochineal, have a degree of management that is close to domestication. More recently, other species of economic interest such as edible insects, have been subject to management methods which approach domestication.

It is of vital importance to take care of the biodiversity that is subject to human management, in order to allow the country to maintain a strategic supply of products specific to unique niche markets, as well as to be competitive. It is therefore essential to look after the caretakers of this biodiversity (the indigenous and rural populations) if we wish to ensure its long-term conservation.

17 *An important part of the natural capital of Mexico is owned by indigenous and rural communities. This implies their involvement in the provision of the environmental services generated by ecosystems in those territories, not only to the local populations, but to society in general.*

Indigenous and peasant farming communities, with their natural capital management practices which originated in Mesoamerica and Aridoamerica, are found both within and outside the system of Protected Areas (PAs), transforming the natural spaces into managed landscapes. This identifies them as what has been called "people of the ecosystems". We have evidence that the protection and management of natural resources conducted by the indigenous and rural communities, even under new schemes of ordinance and use, can be relatively efficient in various parts of the country. This underlines the notion that the indigenous people can—and must, where possible—be active participants in a conservation strategy that includes, but transcends, PAs.

Around 50% of the areas affecting the upper tributaries of the major watersheds of the country are occupied by indigenous communities, and represent almost a quarter (23.3%) of the total rainfall catchment in the country (table 4). At the national scale, half of the regions where most rainfall occurs are located within the territories of rural or indigenous peoples.

Together, the territories of the indigenous communities represent 14.3% of the national area (Fig. 9), and within these almost all of the vegetation types in Mexico are represented. Most humid tropical forests, cloud forests and humid temperate

forests, which together contain a very high biodiversity, are under the custody of indigenous or rural communities (Fig. 10). One third of the federal PAs of the country, and 26.2% of its land area, include rural and indigenous territories, while nearly 19% of the population within such PAs is truly indigenous. It is therefore clear that the conservation of a significant portion of Mexico's biodiversity and ecosystems, along with the services they provide, is dependent on the conservation of rural and indigenous territories. For all these reasons, we suggest that the inclusion of the opinion and active participation of these groups is a vital aspect in the development of management plans for these areas.

Table 4 Water capture in basins that include territories of indigenous communities (includes only those with a water capture greater than 15 000 Mm^3 in the entire basin) (chapter 15, Vol. II)

Hydrologic region	Basin	Indigenous groups*	Water capture in entire basin (Mm^3)	Water capture in indigenous territory (Mm^3)	Percentage of entire basin water capture in indigenous territory
Western Yucatán	Champotón River and others	5, 6, 13, 14, 15, 16, 17, 34, 41, 42	16 900.53	5 693.12	34
Northern Yucatán	Yucatán	17	45 146.30	39 662.74	88
	Quintana Roo	14, 17	18 604.81	14 438.05	78
Eastern Yucatán	Closed Basins-B	5, 17, 31, 39, 41, 42	26 487.60	18 916.63	71
	Bay of Chetumal and others	5, 13, 15, 17, 25, 34, 42	20 037.81	5 401.67	27
Sinaloa	Fuerte River	19, 35, 37	27 598.63	16 311.07	59
Presidio-San Pedro	San Pedro River	9, 12, 26, 37	27 123.95	9 295.92	34
Papaloapan	Papaloapan River	3, 4, 10, 20, 23, 24, 27, 30, 32, 33, 43	87 092.44	50 392.13	58
Pánuco	Moctezuma River	11, 21, 22, 24, 25, 28, 29, 31, 36, 39	40 455.37	12 161.09	30
Grijalva-Usumacinta	Lacantún River	5, 7, 8, 14, 16, 18, 38, 41, 42, 44	34 936.77	26 997.34	77
	Grijalva River-Villahermosa	5, 6, 41, 42, 44	55 969.91	23 676.07	42
	Grijalva River-Tuxtla Gutiérrez	38, 41, 42, 43, 44	22 075.46	6 797.86	31
	Chixoy River	5, 6, 18, 41, 44	33 891.86	11 147.27	33
Costa Chica-Verde River	Atoyac River-B	1, 2, 4, 23, 24, 40, 43	21 109.98	12 040.22	57
Coatzacoalcos	Coatzacoalcos River	3, 20, 23, 24, 27, 32, 33, 39, 41, 42, 43, 44	54 769.35	26 999.74	49
Balsas	Atoyac River-A	28, 29	25 576.28	5 298.21	21
Total			**557 777.05**	**285 229.13**	**51**

* 1 Amuzgo; 2 Chatino; 3 Chinanteco; 4 Chocho; 5 Chol; 6 Chontal of Tabasco; 7 Chuj; 8 Chuj-kanjobal; 9 Cora; 10 Cuicateco; 11 Huasteco; 12 Huichol; 13 Ixil; 14 Kanjobal; 15 Kekchi; 16 Mame; 17 Maya; 18 Maya lacandón; 19 Mayo; 20 Mazateco; 21 Matlatzinca; 22 Mazahua; 23 Mixe; 24 Mixteco; 25 Nahua; 26 Nahua of Durango; 27 Nahua of southern Veracruz; 28 Nahua of Guerrero and the Central Plateau of Estado de México and Oaxaca; 29 Nahua of San Luis Potosí, northern mountains of Puebla and northern Veracruz; 30 Nahua of Zongolica-Pico de Orizaba; 31 Otomí; 32 Popoloca; 33 Popoluca; 34 Quiché; 35 Tarahumara; 36 Tepehua; 37 Tepehuán; 38 Tojolabal; 39 Totonaca; 40 Triqui; 41 Tzeltal; 42 Tzotzil; 43 Zapoteco; 44 Zoque.

Figure 9

Current territories of the indigenous people of Mexico (chapter 15, Vol. II).

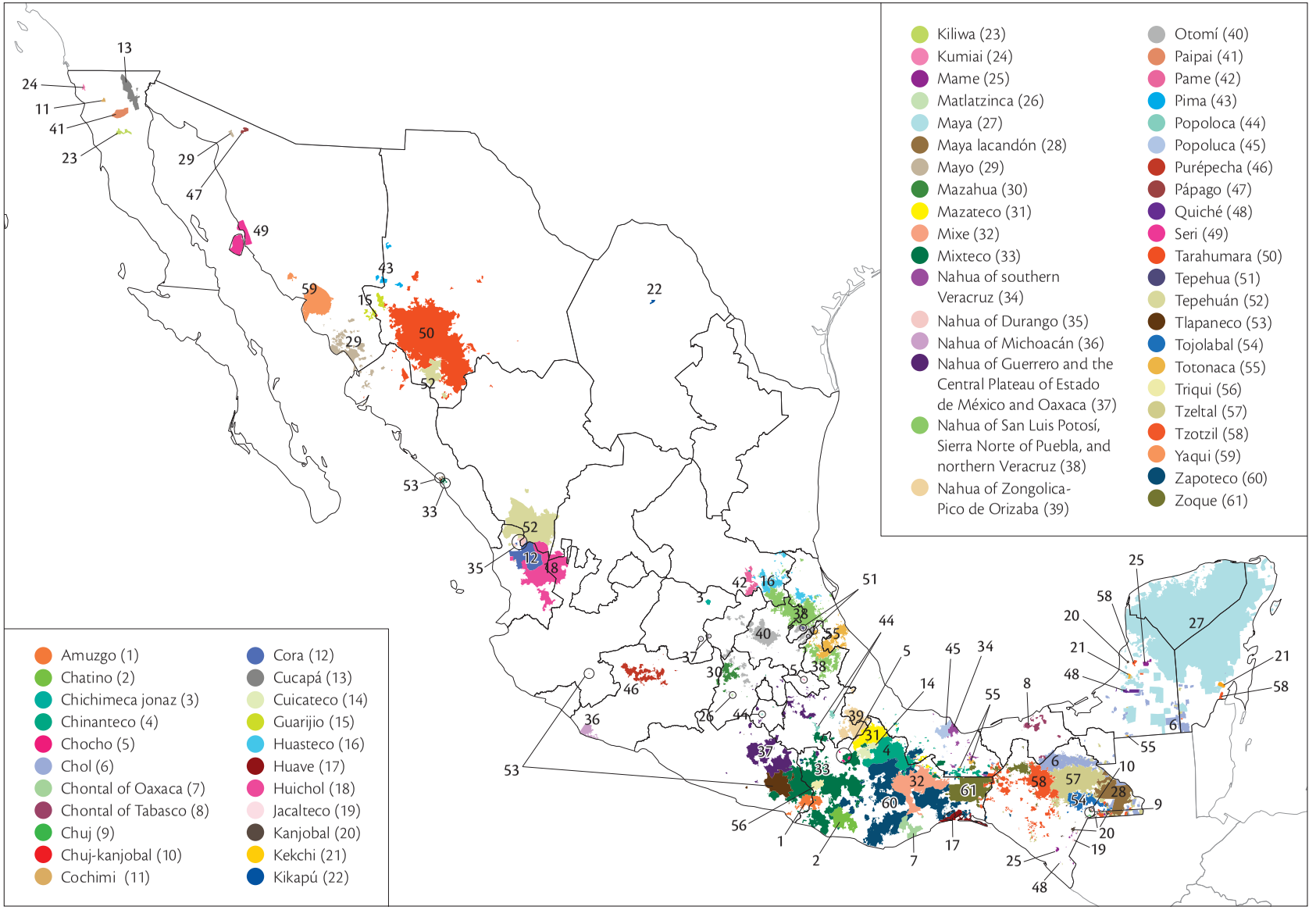
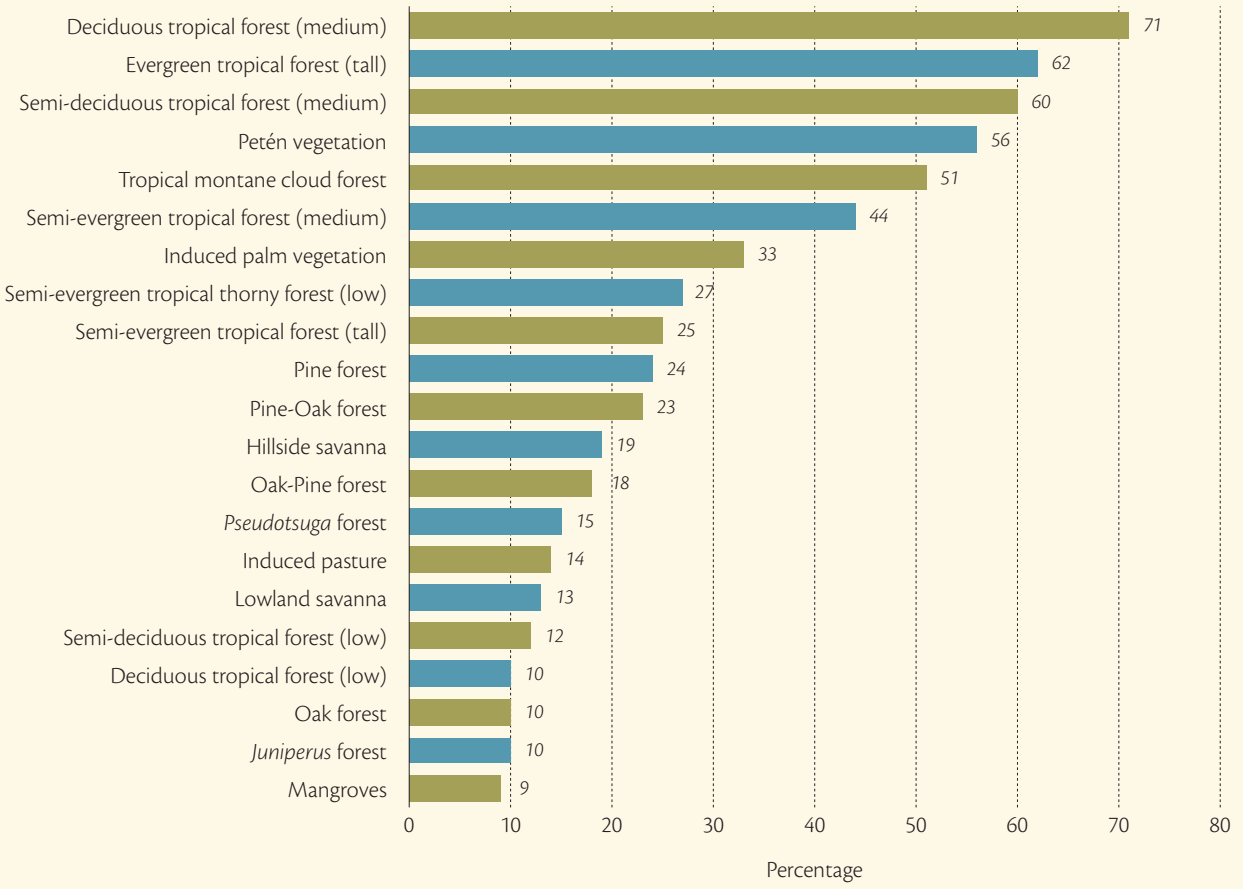


Figure 10

Percentage of coverage, in indigenous territories, of different vegetation types in Mexico (chapter 15, Vol. II).



18 *Scientific research relating to the knowledge and the sustainable use of Mexico's biodiversity faces constraints, legal barriers and a level of support that hinders its future progress.*

The scientific exploration and commercial utilization of the biological diversity of Mexico requires a modern and efficient legal framework. This will enable progress in the understanding and use of our important biotic resources, while simultaneously protecting the public interest and rights of communities and owners of rural lands.

The ability of our country to increase our knowledge about the species that inhabit our territory depends chiefly on a number of factors; the number of institutions maintaining scientific collections in Mexico, their operational strength and resources available to continue explorations of the various areas and critical

groups of organisms, and, of course, the human capital devoted to the study of these groups of animals, plants and microorganisms.

It is of strategic importance to maintain and increase an up-to-date species inventory of species of Mexico, especially of the economically and ecologically important groups. It is also necessary to support the institutions and researchers that develop the modern methods and accumulate the knowledge required to produce these inventories.

In this regard, it is also very important to improve the existing legislation which controls scientific collection in our country. There are still wide gaps in regulation and definition. There continues to be—in areas where regulations actually exist—a large degree of overlap, often disconnected, between the laws governing forestry, fishery, wildlife and agriculture. Areas such as the exploration of biotechnology do not have proper legal regulation, which prevents Mexican public institutions from conducting research aimed at both solving problems of national importance and the advancement of fundamental science. Moreover, there is no adequate legal certainty of the rights of indigenous and rural communities and of private landowners. In this way, the comparatively huge advantage of Mexico's biological richness remains on the margins of major advances in biotechnological science, unlike the situation in other countries such as China, India and Malaysia.

A definitive and comprehensive debate on these issues must be held in the country. The Wildlife Act may be the legal framework most appropriate to complete the proper definition of all those elements that are still ill-defined.

19 *We must use the knowledge gained so far as a strategic advantage for better decision making, incorporating a long term vision, expanding the scope and relevance of that knowledge.*

The enormous biological and ecological diversity of the country is of such magnitude that enormous gaps of knowledge still remain. While this perception is certainly correct, we can also see that, considering the scale of that diversity and the relative youth of our scientific development efforts, with the work done by foreign scientists and the knowledge accumulated by the indigenous groups, we have managed to amass a significant body of information. In this sense, Mexico has an infrastructure of information that is particularly favorable, compared to other countries of similar biological wealth and comparable scientific development. This body of knowledge should provide the basis for making informed and correct decisions concerning the use of our natural resources by those responsible in the various levels of government and for society, informed with that knowledge, to be better educated to assess the options and consequences of various actions taken by the government and other stakeholders.

The city of Motozintla in Chiapas, divided in two by the swollen Mazapa River in 2005.

II

Mexico's biological heritage has historically benefited the population of the country, however, the irrational nature of its use, overexploitation and the impact of economic growth have resulted in the severe deterioration of ecosystems and the environmental services on which humankind depends for development and welfare.

Our country has achieved tangible progress in terms of gaining more and better information to help understand the issues of biodiversity conservation as well as to conceptualize why we must better understand this problem. It is now proposed, as this study focuses on, to envisage problems on biodiversity conservation in terms of an erosion or loss of the results of organic evolution as expressed in the populations, cultivars, species and ecosystems of Mexico, and the anthropogenic deterioration of ecosystem functionality, which translates into a loss of environmental services, on which the wellbeing of all people ultimately depends.

However, efforts to quantify ecosystem processes, and to adequately relate environmental services with welfare, are incipient. This is the case not only in Mexico but worldwide; however, they represent a line of research having not only academic but also strategic importance, particularly in a megadiverse country with conservation problems as acute as ours. More rudimentary still are the efforts to increase in society the perception that the conservation of ecosystems and their services is an issue of central concern for the national wellbeing.

As stated before, Mexican society obtains many essential products, such as food, fodder, timber and pharmaceuticals, from natural systems. These products represent an important part of the national economy, and represent an essential part of the subsistence economy, which sustains some 20% of the population.

The statistical information available for Mexico, regarding products and services arising from the use of ecosystems, has a number of deficiencies. For example, when we started this work, the most recent agricultural census was taken in 1991, and the latest version was only completed in 2007 to be published in late 2008, but by March 2009 this was still not available to the general public. In other cases, several series of chronological data are incomplete, or were produced in

such forms as to be incomparable from one period to the next. This makes it extremely difficult to analyze the balance, in terms of gains and losses, resulting from the transformation of ecosystems. However, the available data shows that in general there has been an increase in the procurement of services of provision or supply from our ecosystems.

20 *The biodiversity and ecosystems of the country show the symptoms of centuries, even millennia of anthropogenic impact, which has become particularly acute in the last 50 years. Deforestation, overexploitation and pollution of ecosystems, the introduction of invasive species and climate change, are direct causes of the loss of our natural capital, and are a response to indirect factors such as demographics, public policy and harmful technological developments.*

In the past two centuries and particularly in the last four or five decades in Mexico, as in the rest of the world, human activity has become a key factor in the profound change of nature and ecological processes. It could be said that we live in a new special era, the "Anthropocene", characterized by the intense environmental footprint of human activity on the ecosystems that support biodiversity.

There are social, economic and political factors that are considered to be root, or indirect factors, which in turn induce other direct factors, such as the transformation of vegetation cover for food production, overexploitation of components of biodiversity or the introduction of invasive alien species; the impact of alien species in island ecosystems is a representative example. In the near future there will be impacts which are difficult to predict, because they are synergic, due to anthropogenic climate change or pollution of ecosystems by the many products of human activity (Fig. 11).

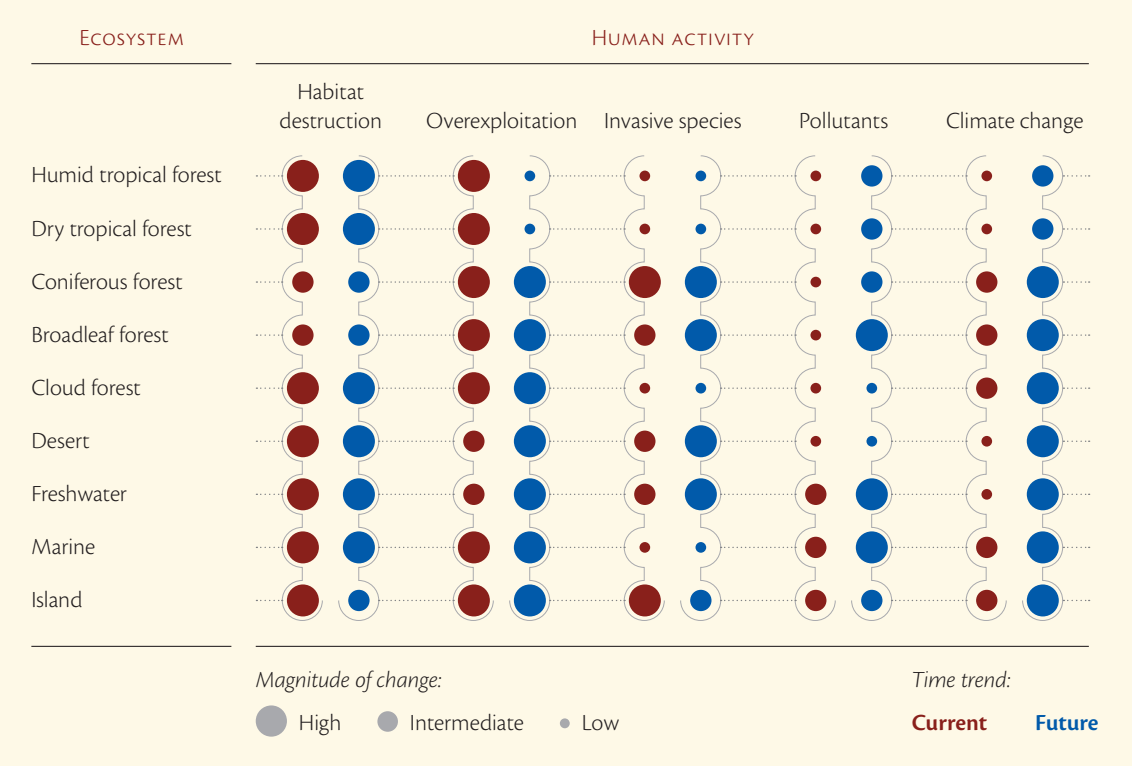
In common with the rest of the planet, the factor of highest impact in the loss of ecosystems and biodiversity has been the deforestation of natural ecosystems for food production. By 1976, the original extent of vegetation cover in the natural ecosystems of Mexico was reduced to 62% and by 1993 had shrunk to only 54% of its original area. Coverage of tropical and temperate forests in the country represented only 38% of their original extent by 2002, with the largest losses taking place in the tropics (Figs. 12 and 13; see chapter 1 of volume II).

A significant proportion of the remaining vegetation is fragmented and in various states of disturbance with an abundance of secondary vegetation, i.e. vegetation that is in different processes of recovery or deterioration.

Although information on wetlands or semi-aquatic environments is very fragmentary, it is evident that these environments have suffered very serious impacts. In the freshwater bodies of Sonora and the Comarca Lagunera, at least 92 springs and 2 500 km of rivers have dried up, surface waters and water tables have de-

Figure 11

Impact of human activity on biodiversity in Mexico: Magnitude of change denoted by circles of different sizes, and temporal trend of ecosystem change (Conabio 2006; chapter 1, Vol. II).



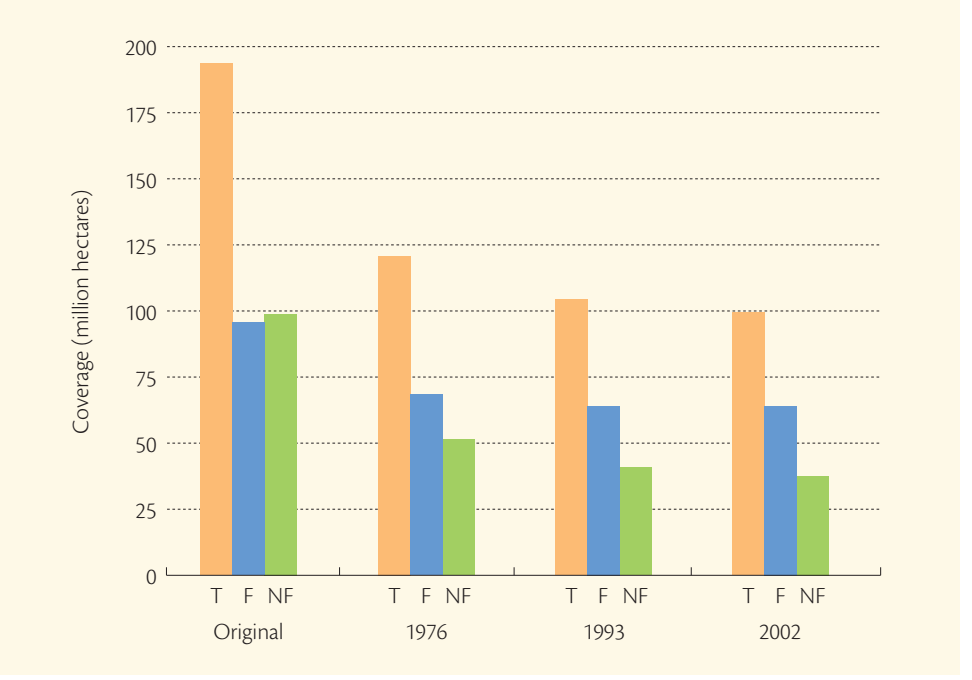
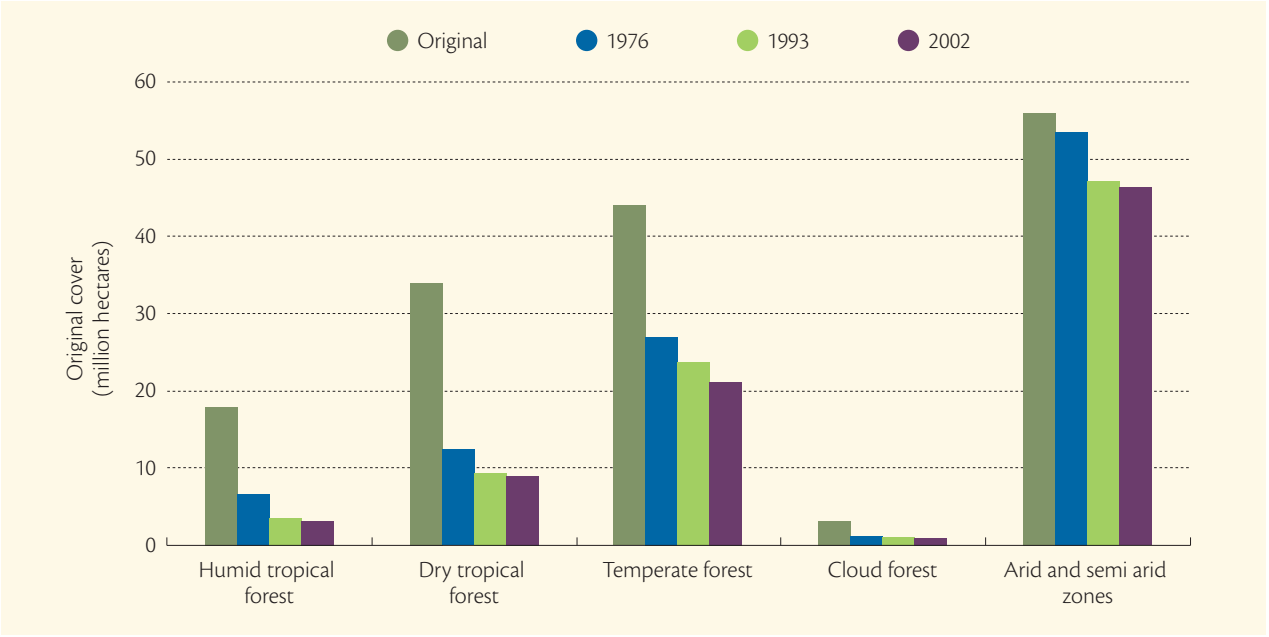


Figure 12

Trends of change in vegetation cover, including total coverage (T), forest (F) and non-forest vegetation (NF) in each year (chapter 1, Vol. II).

Figure 13

Trends of change in primary vegetation cover in various ecosystem types (chapter 1, Vol. II).



creased. Of the nearly 200 species of freshwater fish from this region, 15 have already become extinct, while 120 are considered in danger of extinction (Contreras-Balderas and Lozano-Vilano 1994).

In the coming decades, climate change impacts will be acutely felt, interacting with other stress factors such as overexploitation of species, fragmentation of natural vegetation and other factors of biodiversity loss. Studies of the effects of climate change on ecosystem function have been poorly developed in the country, but an agenda of important work for this purpose can already be seen (IPCC 2007), in which better research on the effects of climate change on biodiversity in Mexico should be central. In spite of this, the information we can collect from general climate models suggests that the effects of climate change will be most severe in ecosystems located in the highest elevations of our mountains and at more northern latitudes and inland lakes.

While not easily quantifiable, there is evidence of recovery trends from areas that have been abandoned mainly through depopulation caused by migration from rural areas, as well as some programs which foster agroforestry systems, the establishment of Units for Conservation and Management of Wildlife (UMAs) and others. These, however, must be adequately evaluated in terms of their effects on conservation.

The environmental costs of development—and the long-term economic consequences—are incalculable, and in many cases impossible to address. However,

the cost of conservation and sustainable management of natural capital will always be much lower than that of recovery or restoration of systems. This fact should be clearly understood in the transversal politics of the different levels of government. This is particularly true in regard to the future ability to supply food to the population of Mexico by the mid-century (about 125 million people, with a higher consumption of food per capita than today). How this challenge is resolved will largely determine the degree of conservation of biodiversity in the country, its ecosystems and the services they will provide to our population in the future. This also applies to marine ecosystems, since less than one third of existing fisheries retain potential for increase.

21 *The increasing concentration of population in urban settlements is an irreversible process of great social, economic and environmental significance. Currently, cities have an unprecedentedly critical impact in the global environment.*

Worldwide, urbanization is a continuous process showing regional and national variants in all countries. As part of this process, megacities have been formed, a phenomenon more common in under-developed countries, but it also occurs in some countries with more consolidated economies. Although high growth rates were a distinctive feature of megacities, it is now common for smaller cities to have higher growth rates than larger cities. Given current trends, in the first 30 years of the twenty-first century it is expected that virtually the entire world's population growth will occur in urban conglomerates. Although occupying only 2% of the planet's surface, the establishment and growth of urban centers has profound environmental consequences in the places where they develop and in those which are under the influence of their demand for goods.

Cities have consumption rates that often exceed their limits (i.e. a large ecological footprint). Population densities in cities exerts a strong pressure on the products and services provided by the ecosystems on which they depend, although it is possible to optimize their use with appropriate development planning. The land use change that underlies urban development compromise many environmental services, including biodiversity. Today, maintaining the highest representation of biotic richness, while preserving the environmental services that this implies, is a fundamental challenge for cities that aspire to become sustainable urban developments.

22 *The impact of human activity in modifying natural ecosystems and the speculative and haphazard occupation of territory for urban purposes or agricultural production, has exacerbated the effects of natural phenomena, causing disasters with very high social and economic costs.*

The geographical position of Mexico, which gives it a privileged ecological and biological diversity, often exposes our territory to hydrometeorological phenomena that, when they are severe, can cause severe socioeconomic impacts. Although these phenomena have been present historically, and several are part of the dynamics that have shaped the ecosystems of the country (e.g. fire in certain coniferous forest), the severity of the effects on the economy and society is the result of anthropogenic alterations of ecosystems and natural patterns of such phenomena, the alteration of hydrological cycles and the reduced capacity of natural ecosystems to buffer their effect (Fig. 14).

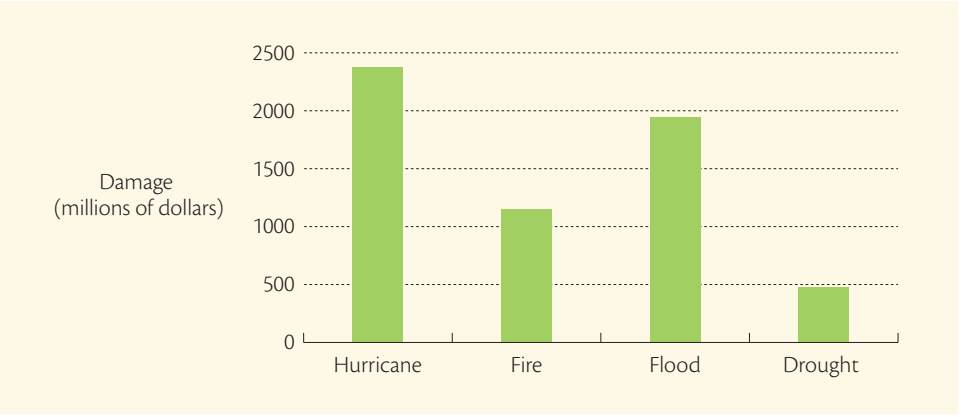
Changes in land use and climate are modifying the patterns of such natural phenomena. Understanding of the complex relationships between disturbance regimes (whether natural or anthropogenic) and biodiversity is still inadequate, but is a fundamental requirement for the conservation and sustainable management of ecosystems.

As a result of its latitudinal location, topography and relationship with the surrounding seas, our country is exposed to extended droughts. More than one third of our territory (35.4%) suffers from this problem, with the most heavily impacted areas being the ecoregions of Baja California, the Chihuahuan Desert and the western Sierra Madre.

Forest fires, which were a natural part of some forest and meadow ecosystems, now generally have an anthropogenic origin and occur with increased frequency, extent and severity. Fires between 1970 and 2007, mostly caused by human activity linked to the use of fire in agricultural practices, affected an average of almost 221 000 hectares per year. The western plateau of Yucatán, the Chiapas highlands, the mountains in the west between Jalisco and Michoacan, and the foothills of the

Figure 14

Economic damage caused by four types of natural disasters in the period 1980-2003 in Mexico (chapter 3, Vol. II).



Southern Pacific coast have suffered the highest frequency of fires within Mexico's territory.

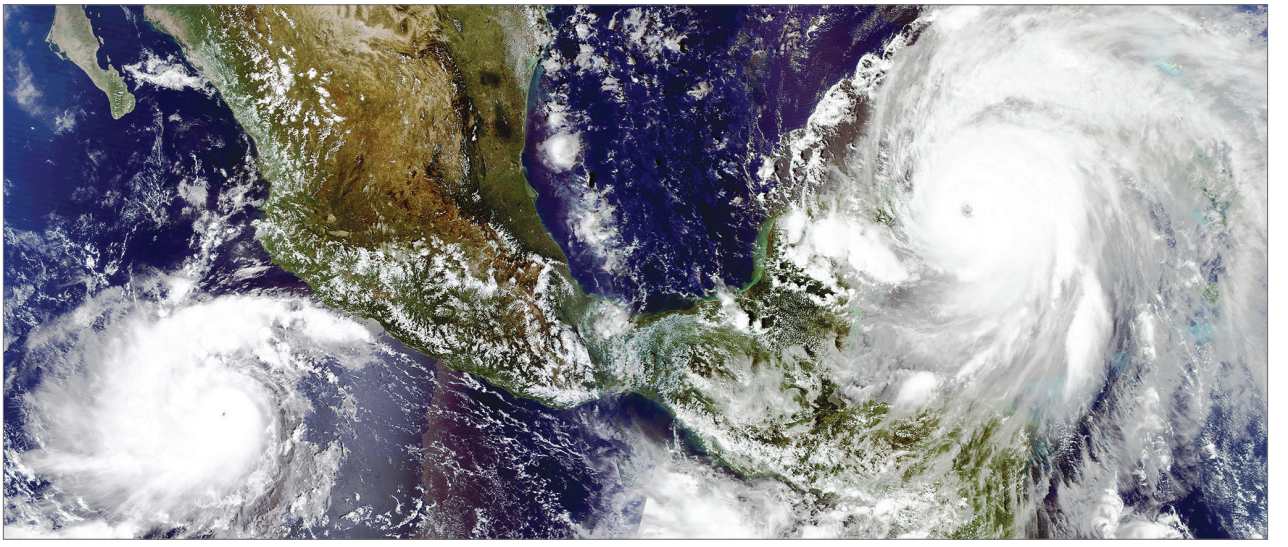
The findings of this study indicate that there has been a higher than expected frequency of fires in fire-sensitive ecosystems, such as humid tropical forests, where the effects are relatively more devastating. The fact that most of these fires are of human origin clearly suggests that they may be managed in a rational way, with measures ranging from control of ignition sources (such as agricultural burning) and fire suppression, through prevention and control, to the application of controlled, prescribed fires.

Since 1999 the contribution of CONABIO to daily fire detection has assisted significantly in the reduction of the effects of fire on the biodiversity of highest value, i.e. that found in protected natural areas or in areas of high endemism, and has also reduced the risks to those who fight the fires.

The frequency of high magnitude hurricanes seems to be increasing. Between 1950 and 2004, 29 hurricanes of categories between 3 and 5 arrived in Mexico—more than one every two years—affecting 25% of the territory, with coastal areas being among those that suffered the most damage, although mountainous regions windward of the hurricanes were also severely impacted. The available information on floods did not allow an adequate evaluation of their effects and there were no predictive models of the susceptibility of regions to the flooding associated with these phenomena.

The costs of hydrometeorological events in Mexico, especially the impact of cyclones and storms, are significant because of the vulnerability created by the removal of forest cover. These costs added to approximately 700 human lives and nearly 700 million US dollars per year during the period 1980-1999. Hydrometeorological disasters caused 4 547 million dollars worth of cumulative damage, including both direct and indirect costs. This was equivalent to 44% of the total

Hurricane Ivan and Tropical Storm Javier in 2004



MODIS satellite image, 13 September 2004. CONABIO-NASA

damage caused by disasters during this period, and consumed more than 70% of the resources of the National Disaster Fund. In the last quarter century, about 3 200 people, who had been in vulnerable conditions and exposed to hydrometeorological phenomena, have been killed (see chapter 4 of volume II).

Data analysis shows that the synergistic effects of these disturbances and their impact on biodiversity are much more severe than when the effects of each of the causes are considered in isolation.

Carefully designed and implemented territorial land use planning could help not only to reduce the impact of natural disasters on biodiversity, as well as the socioeconomic consequences of these phenomena, but also to measure and better assess the ecosystem services that are key for the regulation of these natural perturbations. The prediction of disasters which bring human and economic costs could be significantly enhanced with mitigation measures such as conservation of forest cover in the headwaters of watersheds, maintenance of wetlands (i.e. avoiding human developments) and protection of riparian and coastal zone ecosystems, particularly mangroves and coral reefs which play an important role in reducing the impact of hurricanes.

Due to global warming, it is foreseeable that the frequency of major hurricanes will increase in the immediate future. Proper management and conservation of ecosystems has an important role to play in mitigation measures and adaptation to climate change and should be included in the consideration of a national strategy to counter climatic change. Such sustainable management of ecosystems is also crucial for water resource management in a country such as ours, whose surface is dominated by arid and semi-arid zones and threatened by desertification as a consequence (Fig. 15). Achieving this will also require monitoring systems, which we do not currently possess, and hydrometeorological information of improved spatial coverage and quality.

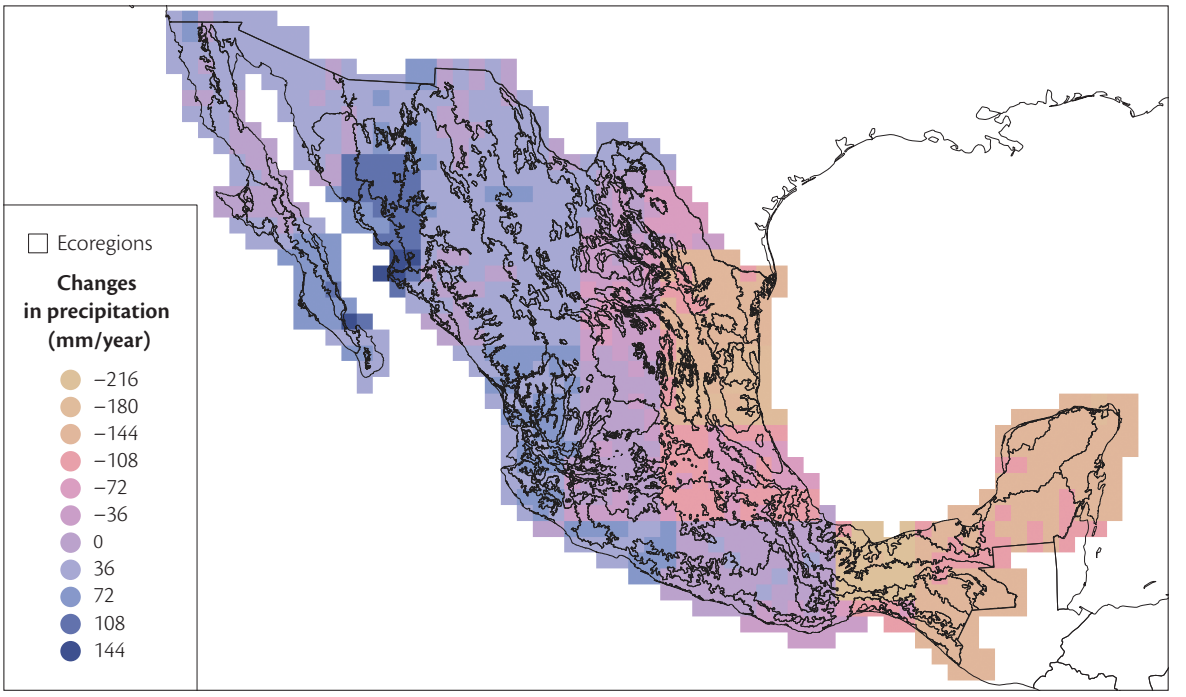
23 *Discrepancies among methods for establishing rates of deforestation in Mexico due mostly to methodological differences, limit the ability to assess long term losses of vegetation cover. However, an assessment of the condition of terrestrial ecosystems shows that deforestation rates have been very severe over the last three decades, and that the natural vegetation has become very fragmented.*

Although in absolute terms the area occupied by urban development is much smaller than that which has historically been transformed by agriculture, the rate of expansion of urban areas at the expense of natural ecosystems in the past 30 years has been much higher (7.4% annually) than the rate of physical expansion of the agricultural sector (0.8% per annum) in the same period. To this urban expansion must be added the effect of towns and cities as centers of demand and

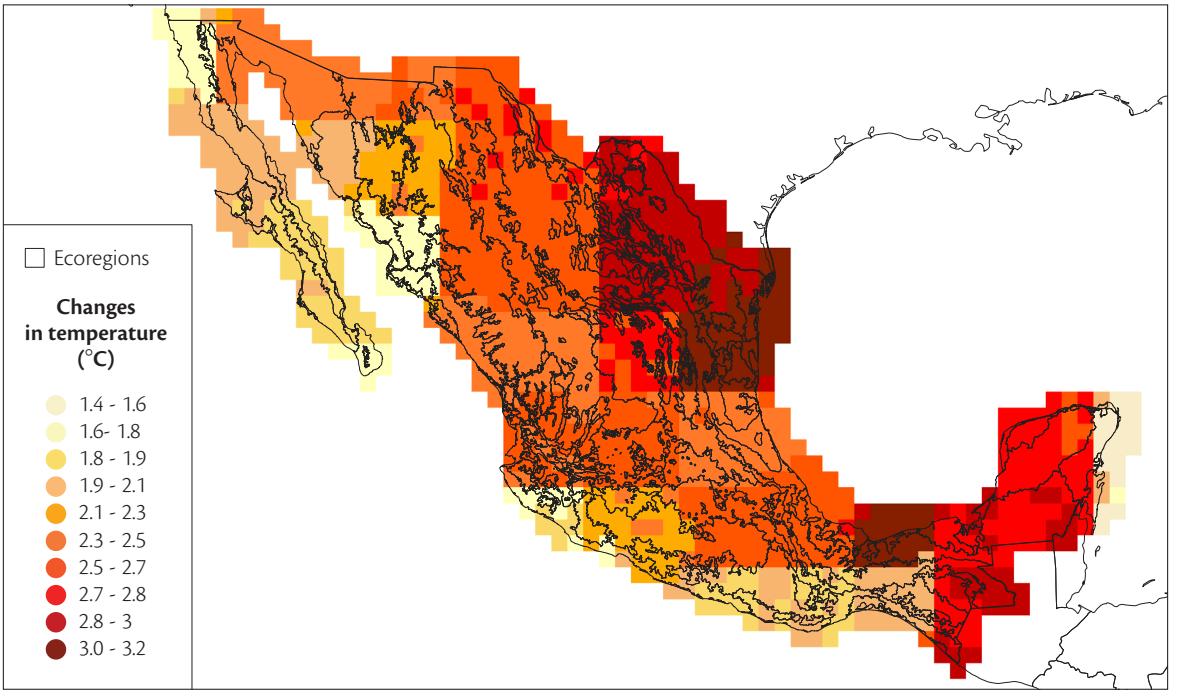
Figure 15

Projections of changes in the factors that govern the processes of desertification: (*a*) annual average rainfall (mm) and (*b*) average annual temperature (°C) expected in Mexico under the HadCM3 model with the SRES A2 scenario for the period 2040-2069 (chapter 3, Vol. II).

15a



15b



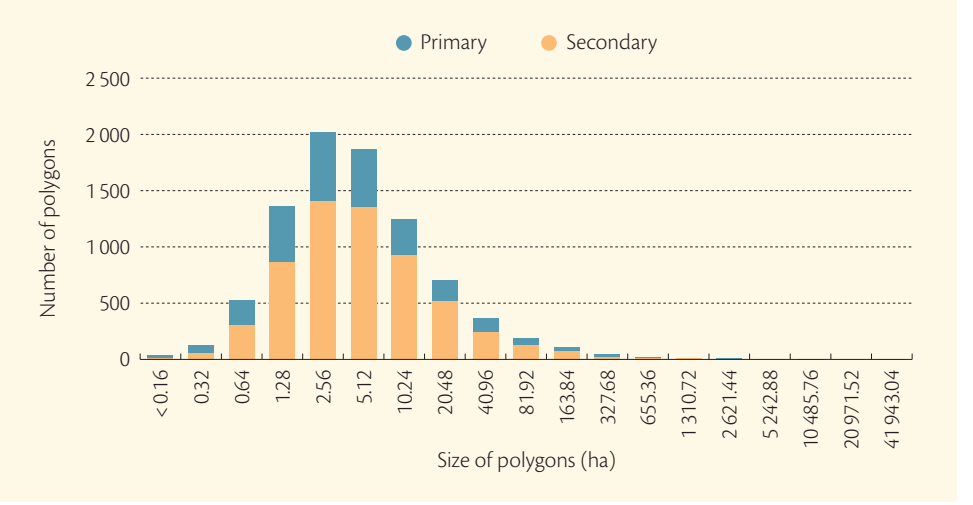
concentration of the production of goods; of levels of consumption and waste, with their respective impacts on the environment through deforestation and biodiversity loss; and the degradation and pollution of soil, water and air.

Fragmentation of ecosystems has reached an acute stage (see chapter 2 of volume II), especially in the case of the vegetation of the humid tropics (Fig. 16), where only a very small proportion of forests (15%) cover areas greater than 20 km^2, and where there is a high occurrence of forest fragments of between 5 and 10 hectares. The situation is similar in the temperate forests, although the proportion of

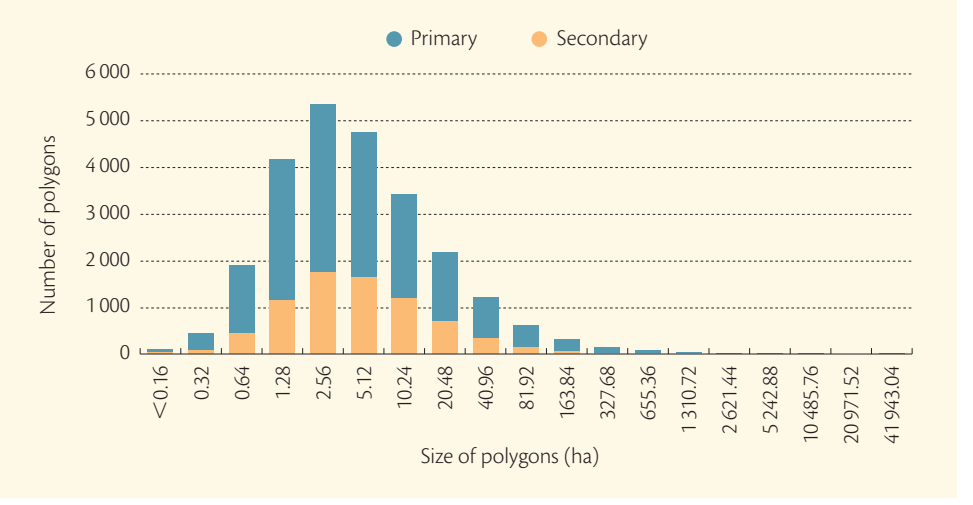
Figure 16

Analysis of vegetation fragmentation. Frequency distribution of the size of polygons that represent vegetation (primary: dark bars; secondary: light bars), (*a*) Humid tropical forests and (*b*) temperate forests, in the INEGI land use and vegetation map, series I, *ca.* 1970) (chapter 2, Vol. II).

16a



16b



secondary vegetation with respect to well-preserved forests is lower than that in the humid tropical forests.

Fragmentation of vegetation has severe negative consequences for the viability of many populations of animals which require large home ranges for their livelihood, which in turn has negative consequences for the viability of numerous plant species.

Although we can be certain about the trend of major loss of vegetation in Mexico, it has proven difficult thus far to conduct studies with acceptable levels of reliability, due to several factors. One basic factor is the extent and territorial complexity of the country, which makes evaluation of the territory, at remote sensing scales appropriate to accurate image interpretation, a very laborious task. Other factors have been the variability that has existed in the past decades, both in quality and scale of mapping information, and in the classification systems of the vegetation that covers our territory. It will be necessary, for future assessments of vegetation coverage of different plant types and changes in land use, to have mapping and vegetation cover classification methodologies which allow chronological studies to be carried out on the basis of fully comparable information. The federal government and academic institutions must ensure that this goal is attainable in the very near future.

24 *The loss, degradation and fragmentation of ecosystems that support biodiversity are the main cause of a marked elevation in rates of extinction, which is especially critical in the case of endemic species.*

Human activity, which has transformed and destroyed natural ecosystems in an attempt to meet various needs for food, materials, etc., is the main cause of species extinction. Globally, it is estimated that the current rate of species extinction is about one thousand times higher than the historical rate. This means that economic activity, particularly from the eighteenth century onwards, represents an impact similar to any global catastrophe that has produced mass extinctions in the past, such as the meteorite impact of 65 million years ago that probably triggered the demise of the dinosaurs.

In our country the situation is no different: the loss of natural ecosystems has been severe. Latest estimates indicate that the country retains only about 50% of its natural vegetation cover (in primary condition).

In addition, over-harvesting of species of economic interest because of their value or use as food, by hunting and large-scale collection, as well as illegal trafficking of species, (which is discussed in chapter 5 of volume II) exacerbates the adverse effect of habitat reduction on these species. To accurately estimate the total number of extinct species of any country is nearly impossible, because of the large gaps in global knowledge about the diversity of the planet.

Table 5 Disappeared, extinct, extirpated, virtually extirpated or feared (but not confirmed) extinct species of vertebrates and plants in Mexico (chapter 10, Vol. I)

Taxonomic group	Extinct[1] in Mexico	Extirpated[2]	Virtually Extirpated[3]	Extinction not confirmed	Total disappeared species
Plants	20	1	—	5	26
Fish	17	12	8	1	38
Amphibians	—	—	—	29	29
Birds	12	5	1	1	19
Mammals	7	1	—	7	15
Total	**56**	**19**	**9**	**43**	**127**

[1] Species extinct: those native or restricted to Mexico whose disappearance has been confirmed.

[2] Species extirpated: those that are extinct in Mexico but still survive but in other countries as part of their distribution area.

[3] Species virtually extirpated: those which do not exist in the wild, but which survive or reproduce in captivity, currently without possibility of reintroduction into the wild.

Table 6 Species included in the NOM-059-SEMARNAT-2001

Group	Subject to special protection[1]	Threatened[2]	In danger of extinction[3]	Probably extinct in the wild[4]	Species in the NOM-059-SEMARNAT-2001
Fungi	7	25	10	—	42
Plants	486	350	141	4	981
Invertebrates	19	11	16	—	46
Fish	30	74	70	11	185
Amphibians	149	42	6	—	197
Reptiles	343	109	14	—	466
Birds	149	107	6	19	281
Mammals	121	124	43	7	295
Total	**1 304**	**842**	**306**	**41**	**2 493**

[1] *Subject to special protection:* those species or populations that might find themselves threatened by factors that adversely affect their viability, and which determine the need to promote recovery and preservation, or restoration and conservation, of associated species populations. (This category can include lower risk categories of the IUCN classification).

[2] *Threatened:* those species or populations, which could find themselves in danger of disappearance in the short to medium term, if the factors that adversely affect their viability continue to operate, causing deterioration or modification of habitat or directly decreasing the size of their populations. (This category overlaps with the vulnerable category of the IUCN classification).

[3] *In danger of extinction:* those species, whose areas of distribution or population size within the national territory have declined dramatically, threatening biological viability throughout their natural habitat, due to factors such as the destruction or drastic modification of habitat, unsustainable harvesting, disease or predation, among others. (This category overlaps with the categories, critically endangered and endangered in the IUCN classification).

[4] *Probably extinct in the wild:* those species native to Mexico, of which wild specimens within the national borders have disappeared, where documentation and studies prove, and live specimens are known to exist in captivity or outside Mexico.

Note: This rule is currently being updated. The list includes species, subspecies or populations.

Source: Semarnat (2002).

To date, we know with certainty that Mexico has lost 127 species, of which 74 (58.2%) were endemic, which means that these species are now extinct from this Planet (table 5). The most important extinctions have occurred in vertebrates of island systems and continental lagoons, particularly in amphibians, of which all the extinctions have been of species endemic to Mexico. Most of the bird species have been lost from the islands in the Pacific Ocean and most fish species are gone from inland waters. Of the extinct plant species, only 5% of plants that became extinct were endemic to Mexico (table 6).

Our understanding of vertebrate extinctions in the country is based on more reliable information; and the extirpations or extinctions of several mammals, birds and freshwater fish have been confirmed prior to 1998. However, sometimes it is impossible to confirm recent extinctions, or to be certain whether they have happened—they may have passed unnoticed until the present—particularly in certain groups of amphibians, invertebrates and inconspicuous plants with very restricted distribution areas. This is due to the lack of comprehensive and extensive monitoring schemes necessary to provide confirmation of extinction.

25 *We have used ecosystems in a similar manner to mining. Instead of managing and maintaining the "factory" of goods and services that ecosystems represent, we have extracted those goods as if from a storehouse of infinite reserves. Now we realize that, in many cases, we have reached the bottom of the store and can clearly see its limitations.*

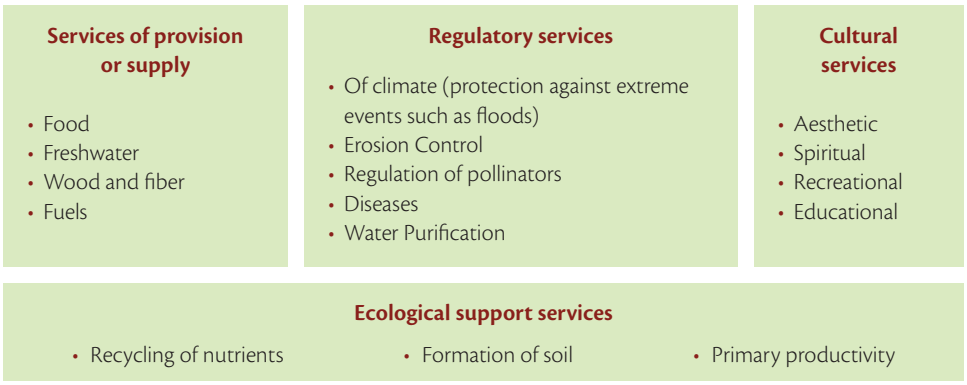
We humans obtain many benefits from the natural ecological systems around us, and from the diversity of species they contain. These services are of different types: some have been the basis for human development (food, fiber, medicines, etc.) and have consequently undergone a very careful valuation, on which markets have been developed. Other services, equally important for human subsistence, have either been omitted from the valuation of benefits we receive from nature (e.g. production of oxygen, soil fertility and its retention in ecosystems, pollinators of plants useful for human consumption, etc.), or are just beginning to be assessed (e.g. water and carbon capture, carbon storage and infiltration to springs, rivers and lakes) (Fig. 17).

The analysis and valuation of these services is an incipient process worldwide, which has begun to be encouraged following the global scale evaluation of ecosystems carried out by the Millennium Ecosystem Assessment (MA 2005). As a result of this work, which involved more than a thousand researchers from around the world, several countries have begun a variety of studies at different scales on the subject. It is, consequently, an emerging area of research in Mexico.

Humankind has been modifying natural ecosystems for millennia to obtain beneficial goods and resources, such as services of provision. There is, indeed, a

Figure 17

The four types of environmental services provided to human society by ecosystems, with examples of each (chapter 4, Vol. II).



transaction or exchange from which we obtain benefits but in order to achieve these, ecosystem services are being sacrificed.

Provision Services

Food production, whether in terrestrial systems (agriculture and livestock farming), or in the sea and epicontinental waters (fisheries and aquaculture), as well as the procurement of wood and fiber, is the result of primary productivity (i.e. the ability of plants to capture solar energy, extract minerals and water from the soil and convert these into plant material which is then consumed by the rest of the organisms in the food chain) of ecosystems and necessarily depends on the photosynthetic process of the primary producers (mostly plants). This is the case even in the inputs required for crops, such as those in aquaculture, that are not linked to the food chain of a natural ecosystem. *In other words we consume, for our survival, solar energy transformed by plants through photosynthesis.*

Agricultural production

Despite the enormous variety of cultivated plants (see chapter 18 of volume I) that were developed in the past in Mexico, at present three crops, one of them not originally from Mexico (sorghum), cover almost 50% of the cultivated area of the country. The area sown to crops in our territory, following an accelerated growth between 1940 and 1965, has since remained relatively stable (slightly less than 23 million hectares) in the last 20 years. However, in terms of hectares under cultivation per capita, the area has diminished by almost 30% between 1980 and 2002.

There has been a slight increase in productivity thanks to an increase—albeit with regional variations—in agricultural inputs. Production of basic grains per capita and yields per hectare remained constant over the past decade, despite large annual changes in sown acreage (Fig. 18), yet national grain production meets only 65% of demand. Notwithstanding the importance of increased food production, the inefficient use of agrochemicals and land clearance in areas inappropriate

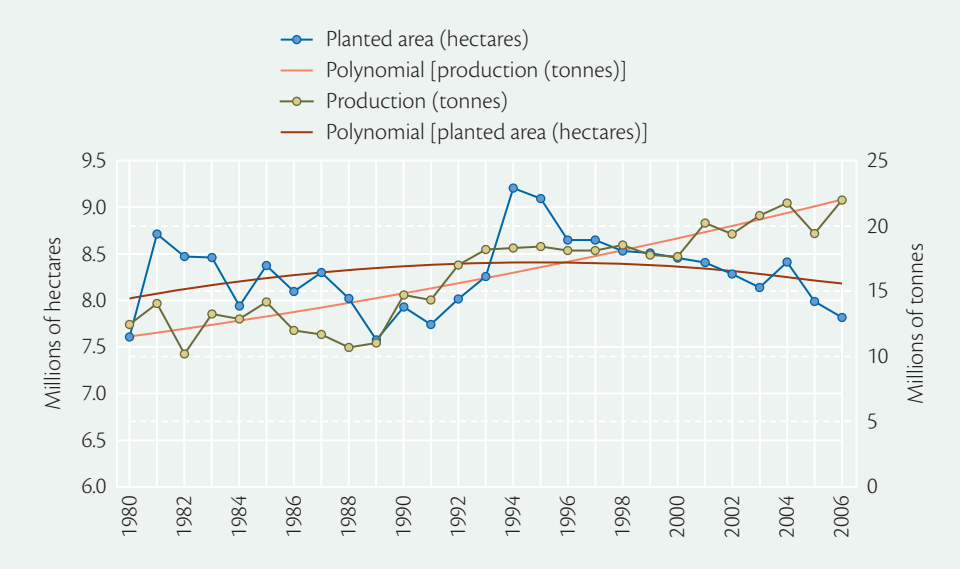


Figure 18

Temporal trends in food production in Mexico between 1980 and 2002. Expansion of the extensive frontier: planted area and production (maize, beans and sorghum) and a polynomial trend summary (chapter 4, Vol. II).

for agriculture, have induced serious erosion, deforestation and contamination of soils and water.

A greater challenge facing us is the sustainable national production of food to meet future demands. This is without doubt an issue of national security, but there is no current discussion regarding how we approach a sustainable agriculture that ensures the food supply for future generations of citizens. This must be achieved while not only avoiding further impacts on natural ecosystems and their services, but helping to restore and replace them in those areas where they have undergone serious deterioration caused by an altogether inadequate level of agricultural production.

Livestock production

Ecosystem transformation for rearing cattle constitutes the most widespread land use throughout the territory, and is the principal factor associated with land use change in the country.

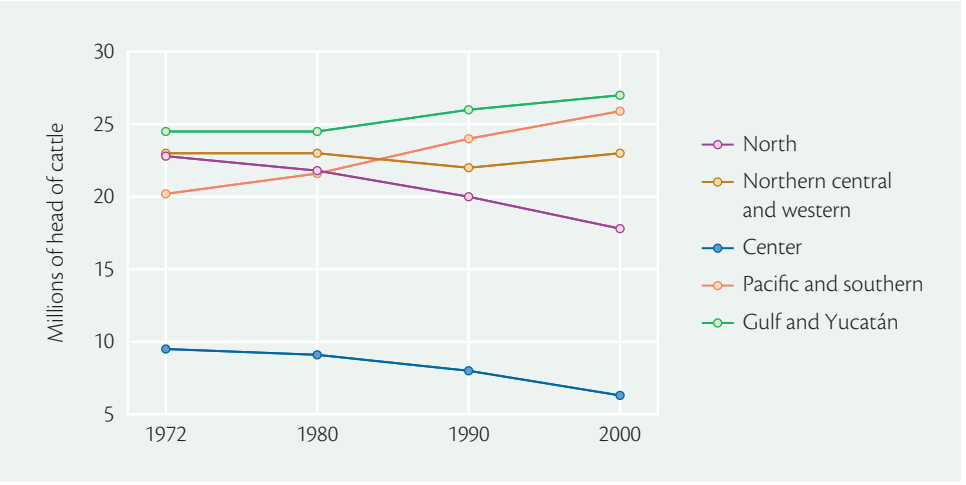
In 1990 it was estimated that around 66% of the land area was dedicated to meat production through large and small-scale livestock rearing, i.e. 129.8 million hectares in 1990 (an estimate that dates back *more than 15 years*, as we do not have [at the time of writing] a more recent agricultural census).

Livestock production reached its fastest growth in the seventies. The process consisted of the transformation of farmland to pasture, clearing of forests (particularly the forests of the humid tropics) for pasture, and the expansion of livestock in the arid and semi-arid ecosystems. In the eighties, animal production stagnated and even recorded decreases. Production of meat and milk from cattle was not reactivated until the nineties (Fig. 19).

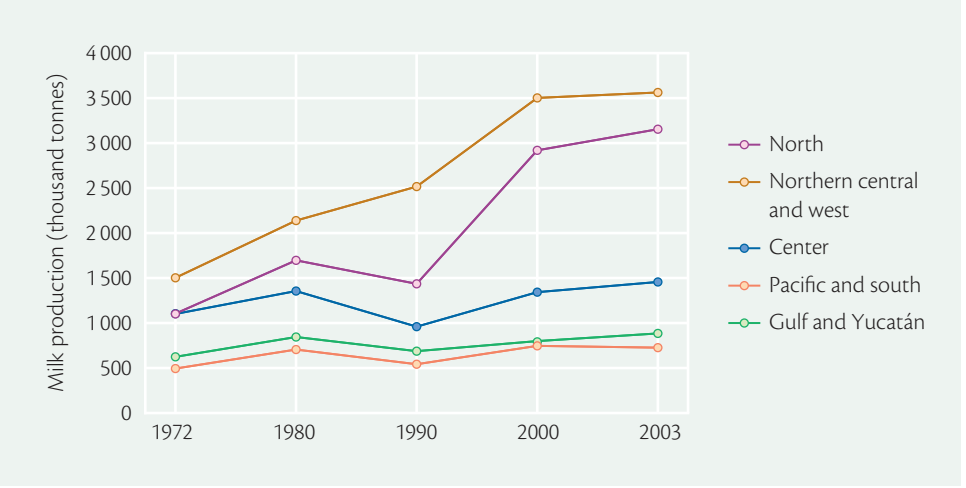
Figure 19

Temporal and spatial trends in food production derived from livestock in Mexico. (*a*) cattle inventories, (*b*) milk production (chapter 4, Vol. II).

19a



19b



We cannot overemphasize that livestock production—particularly in the tropics—is the practically irreversible final stage of the transformation and loss of forest ecosystems.

Fishing

Mexican marine ecosystems have provided between 1.2 and 1.4 million tonnes of fishery products annually for the past three decades. 76% of these products are used directly for human consumption and the rest for indirect human consumption; less than 1% is used for industrial purposes.

Mexico uses 589 marine species, of which 318 are located in the Pacific Ocean and 271 in the Gulf of Mexico and the Caribbean, although the major fisheries concentrate on around 112 species. Because the vast majority of fisheries in our

country are multi-species, and some species are found in various well-defined regions, these 589 species are grouped into 75 management units, with 43 of them in the Pacific Ocean and 32 in the Gulf of Mexico and the Caribbean (table 7) (Sagarpa 2004). However, it is stated in the *Carta Nacional Pesquera* that of the 75 management units, 45 (60%) have reached their maximum yield (fully exploited), while over-exploitation of fisheries resources has been recorded in 20 (26.6%). This means that 86.6% of our marine fishing units are no longer capable of an increase in production, and many of them require management and protection programs to stem their deterioration.

Carlos Sánchez Pereyra (Image Bank CONABIO).

Fishing has direct and indirect (incidental capture) effects on ecosystem (Reynolds *et al*. 2002). Direct extraction of target species has caused most of the known collapses of fish stocks. Almost all fishing involves incidental capture during the process. Some experts claim that fish catches have altered biotic interactions in many regions, by gradually changing the composition of communities from an original abundance of long-lived species and high trophic levels, toward a predominance of short-lived species and lower trophic levels (Pauly *et al*. 1998). This impact of fishing on the food chain significantly increases the likelihood of the collapse of some fisheries (Fig. 20). To address this problem, fisheries management based on an ecosystem approach is now being promoted, rather than focusing on one single species (Pikitch *et al*. 2004).

In summary, the ability of the marine ecosystems of Mexico to provide food through fishing is declining due to overexploitation, deterioration of marine ecosystems essential to complete the life cycles of commercial species, introduction of exotic species and, finally, in a poorly understood ecological process and the effects of climate change. Per capita production of fishery products has also been reduced significantly. The clearest examples of the collapse of fisheries, and the disappearance of fish species in Mexico, include the depletion of sea turtle, totoaba, abalone and grouper stocks during the seventies and eighties, and those of the anchovy and sardine, which showed signs of collapse after the eighties (see figure 21).

Table 7 Distribution and status of exploitation of fisheries management units in Mexico (chapter 5, Vol. II)

	Number			Percentage		
	Pacific	Gulf of Mexico	Total	Pacific	Gulf of Mexico	Total
Deteriorated	11	9	20	25.5	28	26.6
Exploited to the maximum (sustainable)	26	19	45	60.5	59	60
Potential in development	6	4	10	14	13	13.4
Total	**43**	**32**	**75**	**100**	**100**	**100**

Figure 20

Changes over time of the average maximum size and trophic level of the fish community caught by fishing in waters near La Paz, Baja California Sur (Sala *et al.* 2004) (chapter 5, Vol. II).

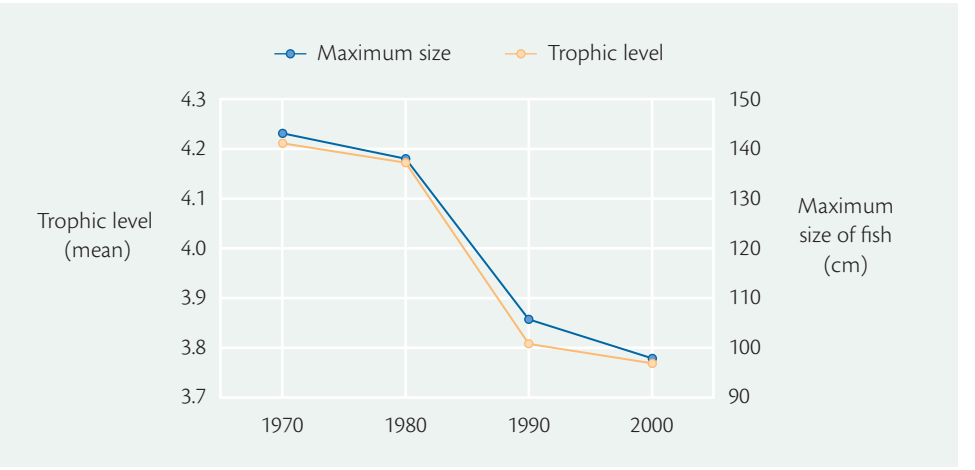
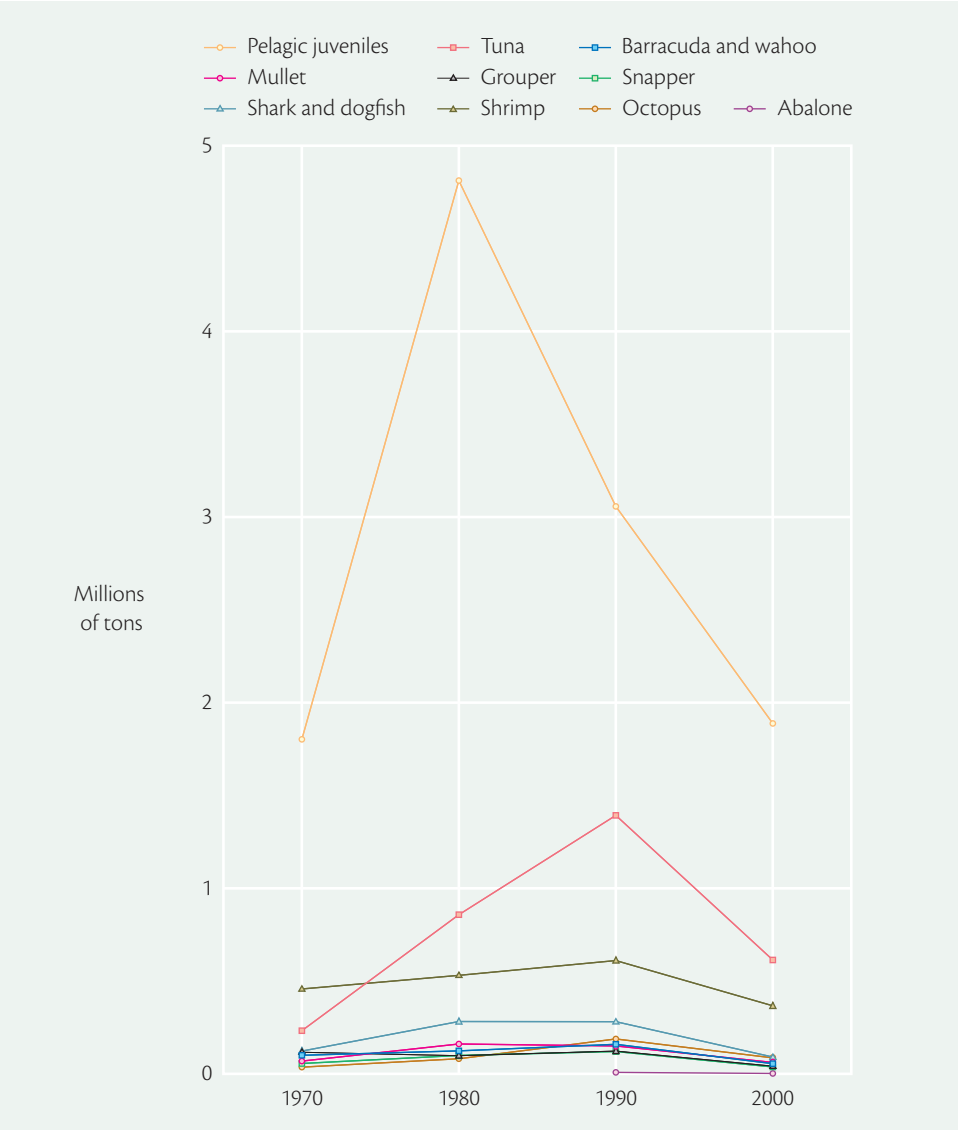


Figure 21

Temporal and spatial trends in food production derived from fishing in Mexico. Volume of fish production in live weight (tonnes) of major species groups between 1970 and 2003 (chapter 4, Vol. II).



Conapesca (the National Commission of Aquaculture and Fisheries) estimates that only 14.2% of fisheries have development potential, 63.3% are at their catch limits and 22.5% have been exhausted.

Aquaculture

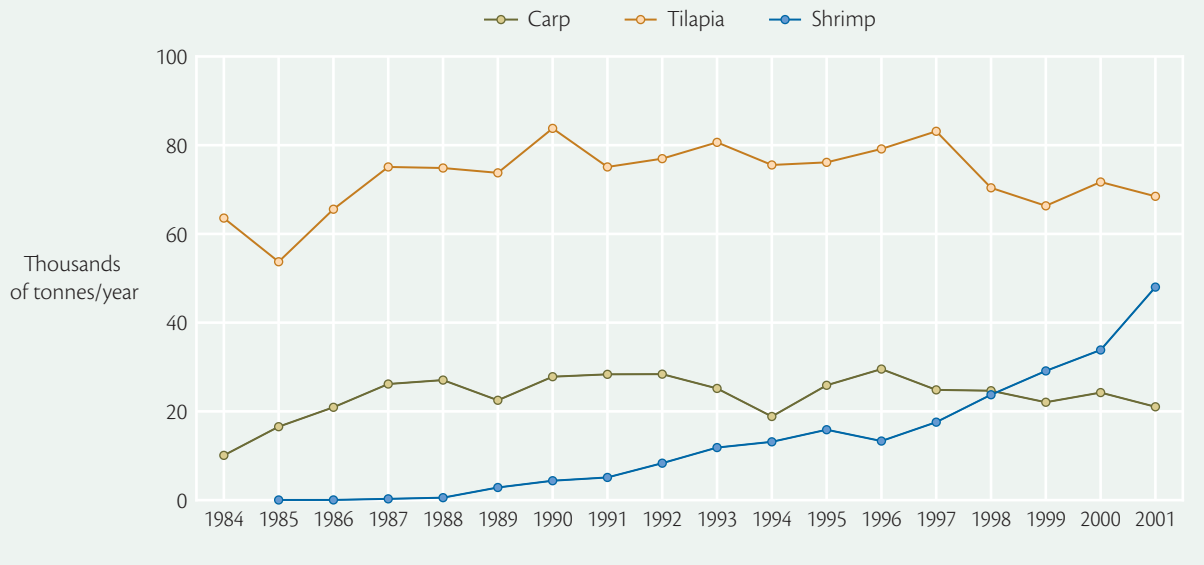
This activity differs from fishing because it encompasses management activities (not necessarily on wild native species) for the harvest of food, such as cultivation; management may include the introduction of exotic species, physical alteration of ecosystems for breeding the species in question (e.g. building ponds), and the use of nutritional supplements with various agricultural or fisheries inputs, and the use of hormones, antibiotics and biocides. Despite the wealth of fish species in Mexico (over 130 species have been identified with potential for cultivation) there are technologies for cultivation for a little more than a dozen species. Aquaculture in inland areas of the country is based heavily on two introduced species: carp (from China) and tilapia (from Africa). Both of these species have led to the local extinction of native species, many of which were endemic.

In coastal lagoons and mangroves that have been transformed, the most common species is shrimp, the production of which has increased significantly (Fig. 22) due to its high commercial value. The supply of food from aquaculture has increased 1.44 times in 20 years, from 144 000 tonnes in 1984 to 207 700 in 2003.

The effect of this cultivation is extremely detrimental to the coastal zones, due

Figure 22

Temporal trends in food production derived from aquaculture in Mexico: production of three types of organisms in the period 1984-2001 (chapter 4, Vol. II).



to the transformation of the mangroves, which are areas of protection and reproduction for many marine species, and also because of the eutrophication of bodies of water due to the intensive use of nutrients and contamination by the chemicals used in their production.

Wood and non-timber forest products

Of the total area under vegetation cover of the country, which is 141.8 million hectares, nearly 66 million are woodlands and forests. Of these, 21.6 million hectares have timber production potential; in the last 15 years, only about 8 million hectares of the former total have been used producing an annual average of 7.53 million cubic meters of wood (mainly from pines) (Fig. 23a). This is an insufficient volume to satisfy domestic demand, and the deficit is covered with imported products causing an increased trade deficit, which climbed to 4 339 million US dollars in 2004, representing about 48% of the trade deficit in Mexico.

Not only are we using less than half of the potential timber production, but we are losing the basic stock without exploiting this potential, due to the high deforestation rates caused by changing land use. Moreover, in various areas that are deforested and converted for agricultural use, the trees felled are not even used for timber.

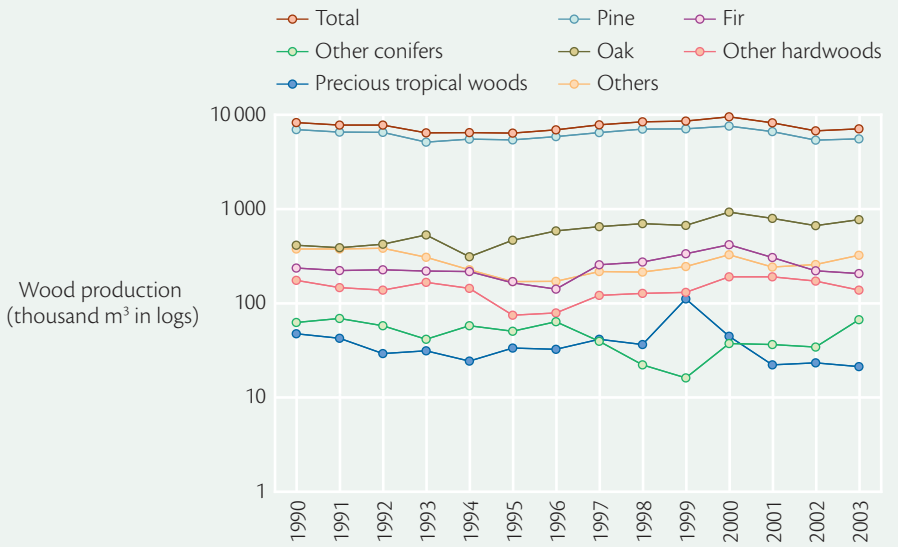
It is estimated that the volume of illegal logging is about 13 million cubic meters per year.

In contrast, Mexico ranks first in the world for community forests certified as sustainable, present both in temperate zones and in the tropics. The country has a certified area of 849 000 hectares and a production of 1.23 million cubic meters of certified timber, equivalent to 10% of the national forest area and 15% of the national timber production, respectively. This is a good model of rational management of resources, with undeniable economic and social benefits, that ought to be encouraged in Mexico, adapting it to the different ecological, social and organizational circumstances of each forest owning community.

Additionally, the production potential of non-timber forest products is considerable (Fig. 23b). Mexico is home to an estimated 3 000 to 6 000 medicinal species, on which the health of a significant percentage of the population depends, mainly those of lower income. Hundreds of non-timber products are used (leaves, fruits, seeds, bark, gum, wax, fibers, dyes, etc.), and these are obtained from 5 000 to 7 000 species present within the different ecosystems of the country.

Mexican ecosystems provide fuel—primarily in the form of firewood—to meet 11% of the total national energy demand, 46% of residential demand and 80% of the rural sector demand. The volume of plant biomass used as fuel is 3 to 4 times greater than the volume of commercial timber extraction, and represents about 19 million tonnes (fresh weight). It is estimated that about 5 million Mexican households cook with wood.

23a



23b

Figure 23

Temporal trends in timber production in Mexico: (*a*) log production by tree types 1990-2003, (*b*) temporal trends in supply patterns of various products between 1994 and 2003: production of non-timber forest products (chapter 4, Vol. II).

The agricultural, livestock production, forestry, fishing and foraging activities can be carried out in the context of management plans that incorporate a great number of species, and are associated with the maintenance of multiple services to minimize negative impacts on ecosystems. This objective should go hand in hand with the respectful maintenance of the cultural background of the rural and indigenous groups of Mexico, of the knowledge they have regarding the natural capital they possess, such as to allow a richer, more dignified and sustainable relation between them and with their ecosystems.

Water

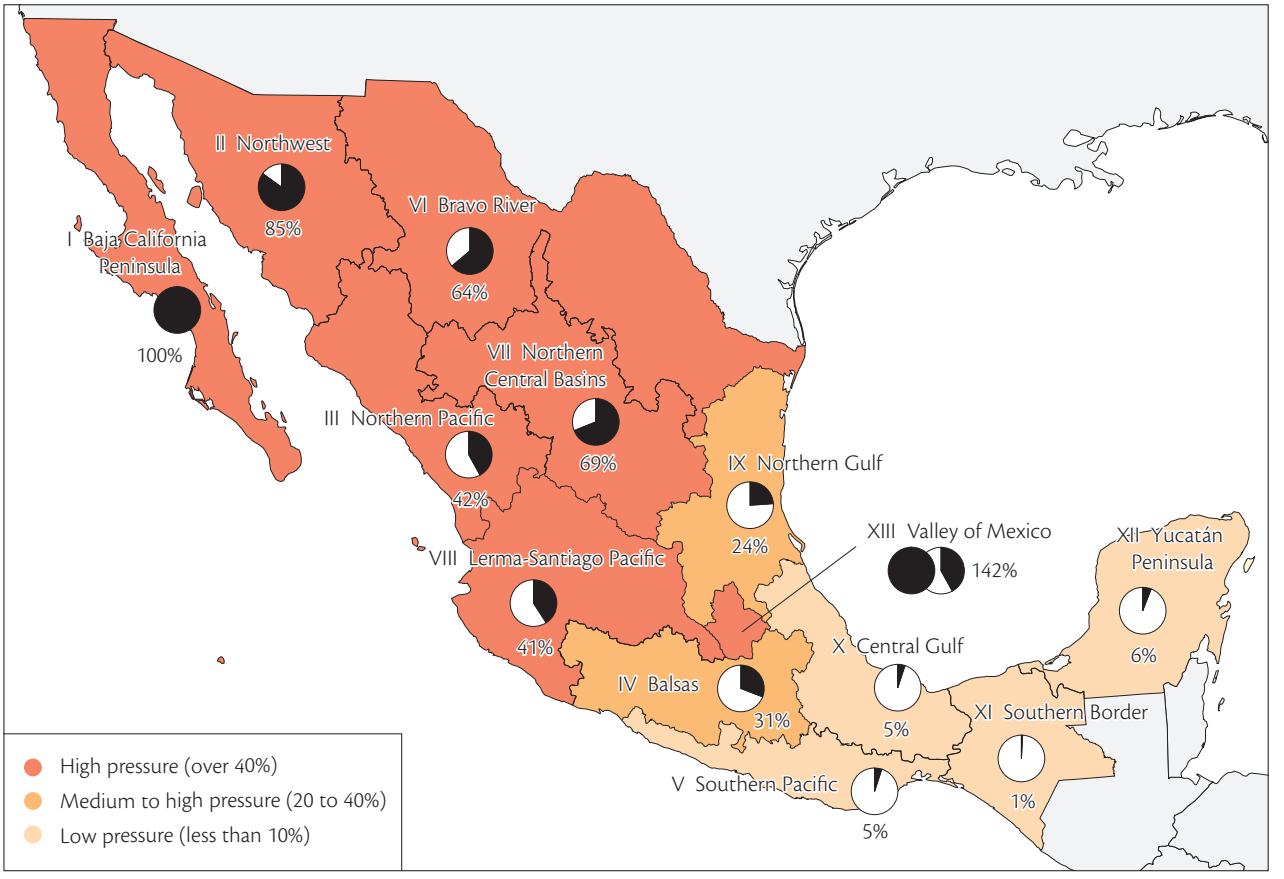
Water and biodiversity have a close and complex relationship. Suffice to mention the obvious importance of the environmental services provided to us by vegetation and aquatic ecosystems. Water is not meant only for the use of people: it is the life blood of the biosphere and is therefore crucial to allow ecosystems to provide a variety of services to humanity.

The average availability of water in Mexico is 4 841 m^3 per capita per year (CNA 2002). However, its spatial distribution is highly uneven; there is high availability in regions such as the southern border and central Gulf areas (with 24 549 and 10 574 m^3 per capita per year, respectively), whereas in the Rio Bravo region of the Baja California Peninsula that figure goes down to about 1 350 m^3 and to just 188 m^3 in the Valley of Mexico, which is considerably less than the threshold of scarcity at 1700 m^3 per capita per year. Furthermore, of the 653 aquifers in the country, 104 are overexploited.

The forecasts of water demands for 2025 indicate that 55% of the country will

Figure 24

Spatial patterns of water supply in Mexico: quantity and quality. Projections of the degree of water stress in different hydrological regions of the country in 2025 (chapter 4, Vol. II).



have very high levels of requirement (Fig. 24), with the areas of peak demand being, in descending order, the Valley of Mexico, the Baja California Peninsula, the northwestern region and the Rio Bravo Basin.

General indicators of water quality show that 73% of water bodies in Mexico are contaminated, since 80% of urban discharges and 85% of industrial discharges are dumped directly into them without prior treatment. The use of untreated wastewater for agricultural irrigation is a common practice on some 180 000 hectares, which puts Mexico in first place globally in terms of irrigation with untreated wastewater. The capacity of dilution, degradation and dispersion of pollutants in the water systems of the country has been seriously altered by the construction of approximately 4 000 dams and other waterworks that have fragmented the systems and modified the physicochemical conditions of the water. The impact on water supply services has had negative effects on other services such as those related to leisure and recreation. For example, some sites are affected by the bacterial contamination of beaches, with the ports of Acapulco, Manzanillo and Veracruz among the hardest hit.

Regulatory Services

These services include processes such as regulation of the water cycle, weather and erosion; pollination of plants of interest to society (including crops, ornamental plants, medicinal plants); and biological control of pests and of disease vectors (see chapter 4 of volume II).

It is difficult to establish the status of regulatory services due to the scarce and fragmentary information available, the lack of monitoring programs of such services and the lack of value our culture places on them. However, recognizable trends in the studies have clearly indicated the existence of processes of deterioration.

The costs of replacing those regulatory services, lost through the destruction or severe disruption of ecosystems, are difficult to quantify. However, some figures give an indication of the possible levels of costs involved. For example, control of diseases caused by a select number of crop pests (some of them introduced) of which we have some information was, in the last 10 years, over 1 200 million pesos (see chapter 4 of volume II). The estimated total consumption of pesticides during 2002 was almost 24 500 tonnes. No data are available for estimating the costs of the environmental impacts of pesticide use.

Pollination

The production of almost 90% of the 130 crop species in Mexico relies on pollinators. About 90% of the wild bee species in the country (a total of 1 589) are pollen gatherers, so they clearly play an important role in pollination of crops. Avocado flowers are visited by at least 70 different species of insects for nectar.

The FAO (2005) estimates that, globally, the value represented by pollinators, for crops could rise to 200 000 million US dollars annually. In Mexico, there are no reliable approximations of this valuation. However, it is known that the annual value of the crop harvest that requires pollination by animal vectors is 63 000 million pesos, while the value of the crops that do not require pollinators is 35 000 million pesos.

Disease Vector Control

In the case of disease vectors, information has been accumulated at a global scale which suggests that the greater the number of wild animals present, the lesser the probability of transmission of diseases to humans (see chapter 4 of volume II). These studies, which have linked biodiversity to the likelihood of disease outbreaks and transmission, are of special interest to public health programs, but are an aspect that has hitherto been poorly studied in Mexico.

Erosion control

Soil is the basic matrix that sustains all terrestrial ecosystems. It also plays a crucial role in the infiltration of water and uptake of carbon. For example, it is estimated that the quantity of carbon stored in the first meter depth of soil is 1.5 times greater than that which exists as above-ground plant biomass, i.e. trunks, branches, leaves, flowers, and fruit, and therefore the soil constitutes most of the important carbon storage in temperate forests. This storage, in addition to natural soil fertility, is lost when erosion strips such storage as a result of the destruction of woodlands and forests.

We have no complete and comparable data regarding the extent of soil erosion at a national scale in Mexico. The information available for 2005 reflects a total of 88.1 million hectares with some form of degradation, a figure equivalent to 45.2% of the national territory. Arid zones are the type of vegetation most affected by soil degradation, as well as areas of rain fed agriculture. The health of terrestrial ecosystems and their associated biodiversity is strongly dependent on the health of the soil.

Cultural services

The extensive knowledge about the natural capital of the country, stretching back to the ancient cultures of our country via sophisticated processes of nature-society interaction over thousands of years, is being undermined by situations of extreme poverty and mass migration of indigenous and rural communities. This is the product of the disintegration of community organizations that have their origin in the adoption of misguided agricultural, economic and commercial de-

velopment policies. In general, the trend of rural dereliction is coupled to a loss of understanding of our natural environment, habits of management and use of resources and the erosion of the internal social structures of these rural and indigenous groups. This involves the loss of traditional knowledge, crucial to achieving sustainability and conservation of natural resources. Several studies show how the massive transformation of ecosystems has caused this loss of traditional knowledge.

These services have great potential to be the basis for a national well-planned ecotourism program; an integrated vision is necessary, as well as on-location training and an appropriate legal framework, among other aspects. Further knowledge is required of the type of services that users wish to obtain in different locations, and of the willingness to pay for such services.

26 *The illegal harvesting of species, which favors the interests of individuals or small groups over that of the public, has had a very negative impact on the country's natural capital. This contrasts with local traditional exploitation of these resources which, in general, rests on sound principles of conservation.*

The irrational and illegal extraction of species within ecosystems is the second highest factor of impact on biodiversity but it can, depending on local circumstances, be the most destructive one.

Most of the available information relates to specific and local case studies, which hinders a proper national assessment of this problem. There is a serious lack of reliable statistical data about what fundamentally is an illegal activity, such as the banned trafficking of wildlife.

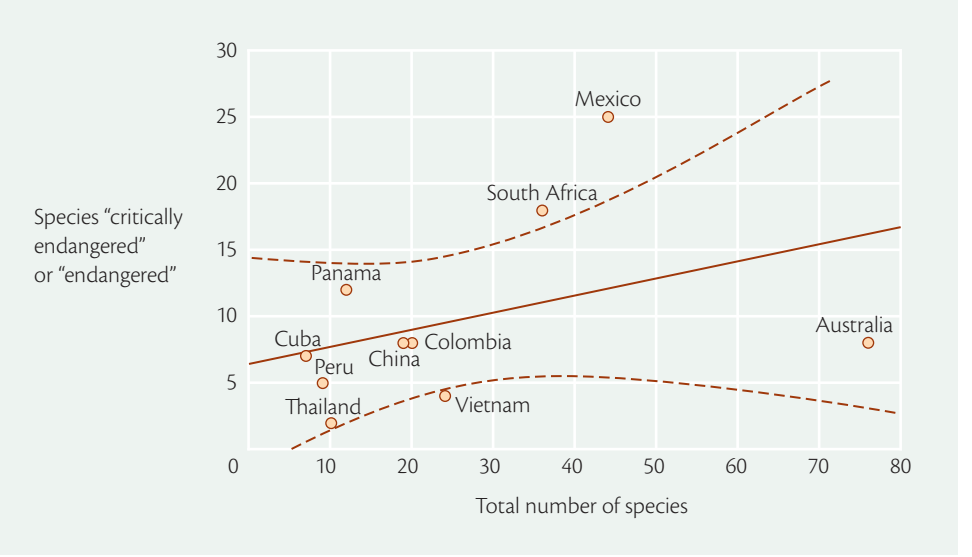
The illegal extraction of plants and animals continues in a marked tendency of growth, with a peak year close to 330 000 specimens, mostly plants, which accounted for between 60% and 70% of the trade. Many of these species are included in the NOM-059-SEMARNAT-2001 (which enlists endangered species) and the CITES lists, which prohibit national or international trafficking. However, it must be recognized that, although the number of impounded specimens covered by this legislation is increasing, this does not necessarily mean that illegal trafficking is rising: it may be that the policying operatives have become more efficient.

The most notable case of illegal exploitation, as discussed earlier, is that of timber: with data unreliable due to variability and uncertainties, it is estimated that between 20 000 and 120 000 m^3 of timber were seized between the years 2001 and 2005 (see chapter 5 of volume II).

Figure 25 shows that our ability to control this illegal trafficking is completely inadequate, even in comparison to other countries of large biodiversity such as

Figure 25

Relationship between species richness of cycads and the number considered by the IUCN to be seriously threatened in several countries (chapter 5, Vol. II).



Australia or South Africa. This figure makes it clear that the risk level at which certain species are found, as an estimator of the trafficking of which they are subject, is well above that which could be expected for our country, given its number of, for example, cycad species, a family of plants especially appreciated for their ornamental value and of which a high percentage are endemic to Mexico.

Although in Mexico the collection and sale of wild orchids is not allowed, extraction for domestic and international sale is one of the biggest problems for conservation of the species in this group. It is estimated that illegal traffic of these plants in the period 1993-1996 was between 9 and 12 million individuals, while the legal trade (for plants grown in greenhouses) reached only 152 000 plants.

Hunting now represents an important activity for rural groups in Mexico. Several studies report hunting intensities among these groups that, in terms of meat biomass, represent important inputs of animal proteins that are close to the average daily intake of beef per capita nationwide.

International traffic of wildlife is a business that represents several billions of dollars annually, and Mexico is a major player in this illegal trade, both in the supply and demand sides of the market. Although there have been an important number of impuondments carried out by Profepa, it is estimated that these represent only about 2% of the illegal trafficking of parrots (parakeets), of which 75% die before reaching the final purchaser. Although there are regulations and incentives for the sustainable extraction of species (System of Units for Conservation and Wildlife Management, SUMA), at least 16 collectivities of song bird and ornamental bird gatherers do not operate under this scheme, but claim a status of "subsistence use" clearly inapplicable to these types of birds and operate with no management plan or evaluation of the status of the bird populations subject to removal.

The variability of data on illegal trade in wild animals suggests that the existing

mechanisms for collecting information are inefficient and unreliable, as is the case with all illegal activities. In the period 2001-2005, Profepa (2006) reported widely varying figures ranging between 50 000 and 100 000, with a maximum of more than 200 000 individual specimens of many different species in 2002.

Overexploitation occurs also notably in the marine ecosystems. We know that globally, many fish stocks are overexploited and that the ecosystems that sustain them have been degraded (FAO 2002). Currently, there is increased recognition that the consequences of large-scale fisheries include several side effects such as habitat destruction, incidental killing of non-target species, changes in population demographics, and changes in the function and structure of ecosystems (Pikitch *et al*. 2004), as well as overinvestment, excessive fishing effort and multifocal pollution (Arenas and Jiménez 2004). According to Myers and Worm (2003), the abundance of high trophic level fish species, i.e. those located at the top of the food chain, has diminished by more than 90% and the exploitation represents more than 30% of total marine production (Dulvy *et al*. 2003).

27 *Invasive species, i.e. those that are introduced beyond their natural range, alter the ecosystems they invade, affecting native species and causing severe environmental and economic damages. They are one of the most important causes of biodiversity loss.*

The effects of invasive species on our native species and ecosystems are documented in an incipient manner, making it difficult to estimate the true economic impact. For those that are considered quarantine pests there are various control measures. However, species respect no boundaries between a managed system and a natural ecosystem so, particularly for wild species, the Invasive Species Program established by CONABIO has developed a national database of exotic species with invasive potential, both for those already established in our territory and those which could become established and pose a risk to our country. This system provides a basis to conduct monitoring programs of those species of greatest risk. There have now been 665 species of exotic plants recorded (table 8); of these, 23 are considered to be of priority interest because of their growth in natural environments, their history of being harmful in other countries and because they are susceptible to control and eradication. It should be borne in mind that prevention is orders of magnitude less costly than programs of control and eradication.

Among the invertebrate species that represent a major hazard, is the cactus moth (*Cactoblastis cactorum*), on which CONABIO conducted a study in 2001 to define areas of greatest risk and potential entry into the country. This moth, detected in 2006 on Isla Mujeres, Quintana Roo, was declared eradicated in 2008, thanks to the early action of the Ministry of Agricultura (Sagarpa) in coordina-

Table 8 Number of species registered in the information system on invasive species of the National Information System on Biodiversity (SNIB), by invasive potential and invasion status (CONABIO 2008b) and total number of exotic species recorded in Mexico (chapter 6, Vol. II)

Group	Environment	Routes of introduction*	Invasive species by invasion status			Species in SNIB	Registered exotic species
			Not established	Confirmation required	Established		
Algae	Marine and brackish water	T, C, N	23	4	18	45	
Plants	Land and freshwater	C, H, N, D	—	—	132	132	665
Molluscs	Freshwater, brackish water, marine, terrestrial	T, C, D	3	1	9	13	
Crustaceans	Freshwater, brackish water, marine terrestrial	C, H, T, D	10	7	17	34	
Insects	Terrestrial	T, C, H, N, D	5	—	7	12	
Other invertebrates	Freshwater, brackish water, marine	T, C, D	7	10	13	30	
Fish	Freshwater, marine	T, C, H, D	—	4	57	61	
Amphibians	Freshwater, terrestrial	C, T, D	—	—	3	3	2
Reptiles	Freshwater, terrestrial	C, H, D	—	—	6	6	8
Birds	Terrestrial	T, C, N, H	1	—	6	7	30
Mammals	Terrestrial	T, C, H, N, D	—	—	15	15	16
Total						**358**	

* T: transport of goods and people; C: trade in live organisms; H: other human activities; N: natural phenomena; D: origin unknown.

tion with the Ministry of the Environment (Semarnat). However, the moth keeps being a serious threat for the destruction of dozens of *Opuntia* species which are the dominant elements of most of the semiarid zones in the Central Plateau of Mexico.

Some vertebrates, such as dogs, cats, goats and mice, pose particularly serious threats on islands, where they have nearly led to the extinction of several endemic bird species. We need to create official instruments of management and to foster a culture of prevention to effectively protect the Mexican islands from the constant introduction of exotic species that represent a serious threat to the biodiversity of these ecosystems.

The case of freshwater ecosystems is remarkable; lakes and rivers are particularly vulnerable to the introduction of alien species, and these ecosystems harbor a high number of endemic species. The NOM-059-SEMARNAT-2001 lists 169 species of these ecosystems, of which eight are considered extinct, 68 in danger of extinction and 74 threatened. This means that 31% of the native species of freshwater ecosystems—the majority of these being fish—are included in this legislation as being under some degree of threat due to, among other things, the invasion of exotic fish. Several groups have already exhibited some extinctions caused

by the presence of alien organisms, and this effect has been increasing to the point that they are currently implicated in the extirpation of native species in over 100 locations scattered throughout the country, particularly among the islands.

Despite the obvious need to implement prevention and control measures, there is still no comprehensive national policy to address issues associated with introduced species in natural habitats. The only existing actions have an agricultural focus, and concentrate on pests of crops livestock or forest species of economic interest.

28 *Genetically modified organisms that are released to fields, as well as to productivity chains and human consumption, must be analyzed and evaluated under measures of biosecurity. This is of special importance in Mexico, which is an important center of origin of genetic diversity and of the domestication of many cultivated plants.*

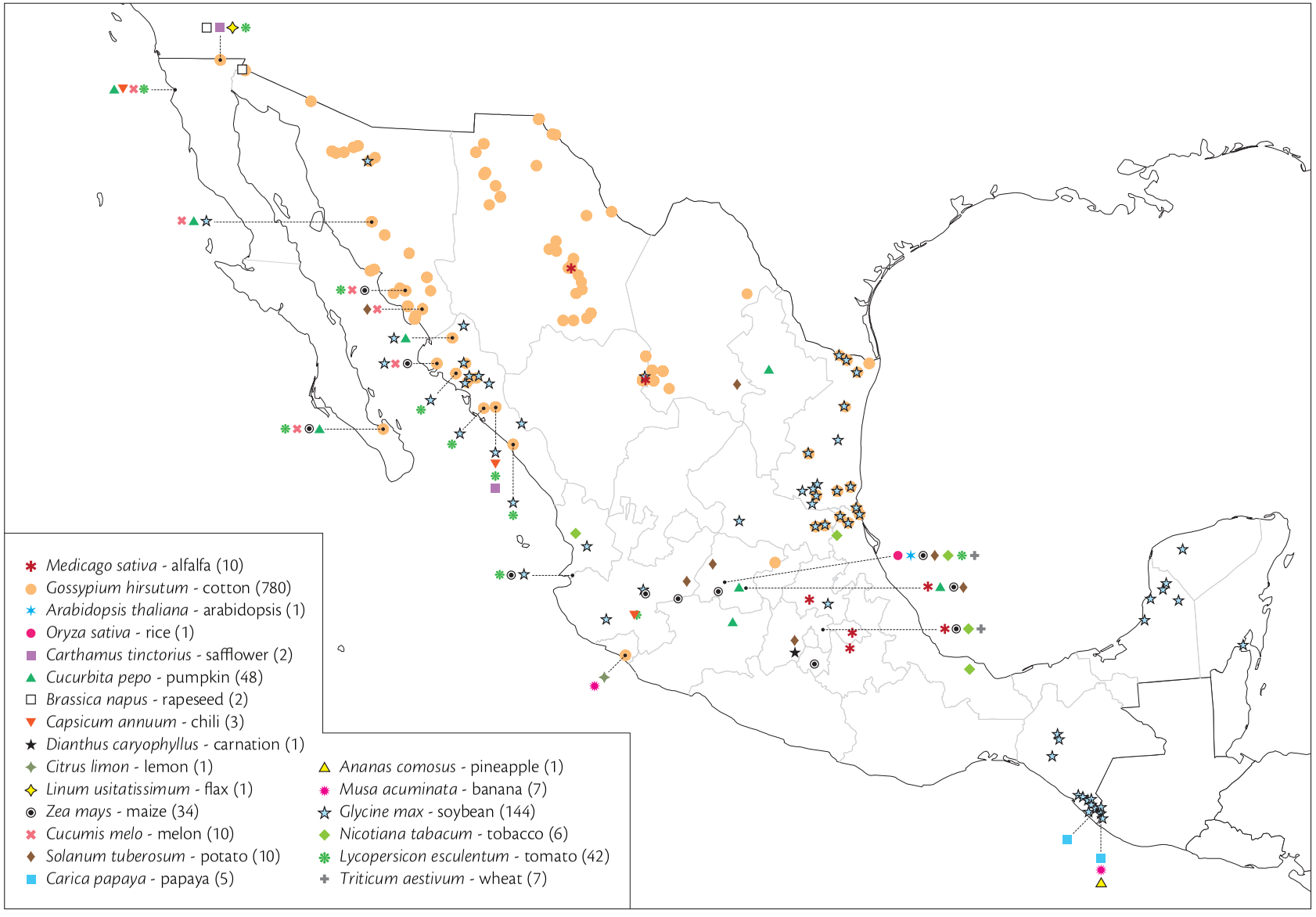
We stated earlier that Mexico is not only a megadiverse country, but also a major center of origin and diversification of crops, many of which have been adapted to other regions of the world and have had an important role in the global economy.

Modern biotechnology has contributed to this diversity—using techniques that differ from those traditionally used in the domestication of plants—by generating new varieties of organisms of economic interest, especially crops. In some cases the products of this modern biotechnology present advantages, but also potential risks to biodiversity, the integrity of traditional varieties of many crops—as is the case in Mexico—and occasionally to the socioeconomic and cultural aspects involved in the process of domestication that Mexican farmers have maintained for centuries. Consequently, there must be a close relationship between the development and supply of genetically modified organisms (GMOs) and the assessment of their potential risks. This requires a case by case analysis considering three crucial factors: the environment, human health and socioeconomic activity. This analysis should also consider risk management, and its broad communication to the society which will potentially put these products into use. Figure 26 illustrates the instances of GMO release that have taken place in Mexico up to the year 2006.

Biotechnology must be developed, but should do so in a safe and responsible manner. The term "biosecurity" directly refers to this, and implies a much wider vision of the choices available to solve problems of food production or other types, as well as applications for environmental remediation. Products which are released to nature, productivity chains and human consumption, should be monitored effectively and efficiently, such that there is absolute certainty that any identified potential risks can be minimized to the lowest level possible (i.e. acceptable under well-defined criteria).

Figure 26

GMO releases in Mexico approved between 1991 and 2006. Brackets indicate the number of releases per culture (chapter 7, Vol. II).



The development of human and institutional capacities should be fostered, ensuring their permanence in order to guarantee, as far as possible, a vigorous but responsible and relevant biotechnology development in Mexico.

29 *The identification of priority areas for biodiversity conservation in a country as diverse as Mexico is a basic tool to facilitate the selection, harmonization and creation of synergies among the various complementary instruments required to achieve the conservation and sustainable use of our natural heritage.*

In 1996, CONABIO, with the participation of a large number of experts throughout the country, began an effort to identify priority areas for the conservation of Mexico's biodiversity. As a result, 152 terrestrial regions were recognized with an area coverage of 515 588 km^2; 70 marine regions covering 1 378 620 km^2 of coastal and marine areas; 110 hydrological regions covering 777 248 km^2 of the country's major watersheds; and 219 areas of importance to the conservation of birdlife, with a coverage of 309 655 km^2.

Such regionalization has served to steer and optimize efforts of study, collection and research, and to a more focused channeling of funding from the various federal and private institutions that provide support for such studies. However, following the commitment made in the seventh Conference of the Parties to the CBD in 2004, various analyses were carried out in Mexico to identify areas of importance for biodiversity conservation, at a finer scale than the one used for the priority regions. These considered different methodologies, the most up to date information, federal, state and municipal protected areas, and the participation of a number of specialists from academia, government and civil organizations. The analysis showed that 11 of the 96 terrestrial ecoregions are not represented in protected areas, and that more than 55% of the ecoregions are under-represented; that biases exist as a greater proportion of highlands (higher than 2800 m) are protected, compared with the rest of the country; and that the types of vegetation with the lowest protection levels are present in dry tropical forests, the Tamaulipas thorn scrub and pine-oak forests.

Moreover, a more detailed analysis was conducted, in which species of restricted distribution, and endemic and threatened species were considered, as well as sites with higher concentrations of species richness and primary vegetation. This revealed that, as a result of the high level of endemism of Mexican biota (Fig. 27a), 16.4% of the continental land area corresponds to unique, high priority areas, but only a small fraction (15.93%) of this area is under any type of official protection (whether federal, state or municipal). In marine environments, 105 priority sites were identified on the coasts, oceans and islands (Fig. 27b). Only 18.33% of the area of these priority sites is declared as protected, so it is essential

Figure 27a

Priority sites for conservation of terrestrial biodiversity (chapter 16, Vol. II).

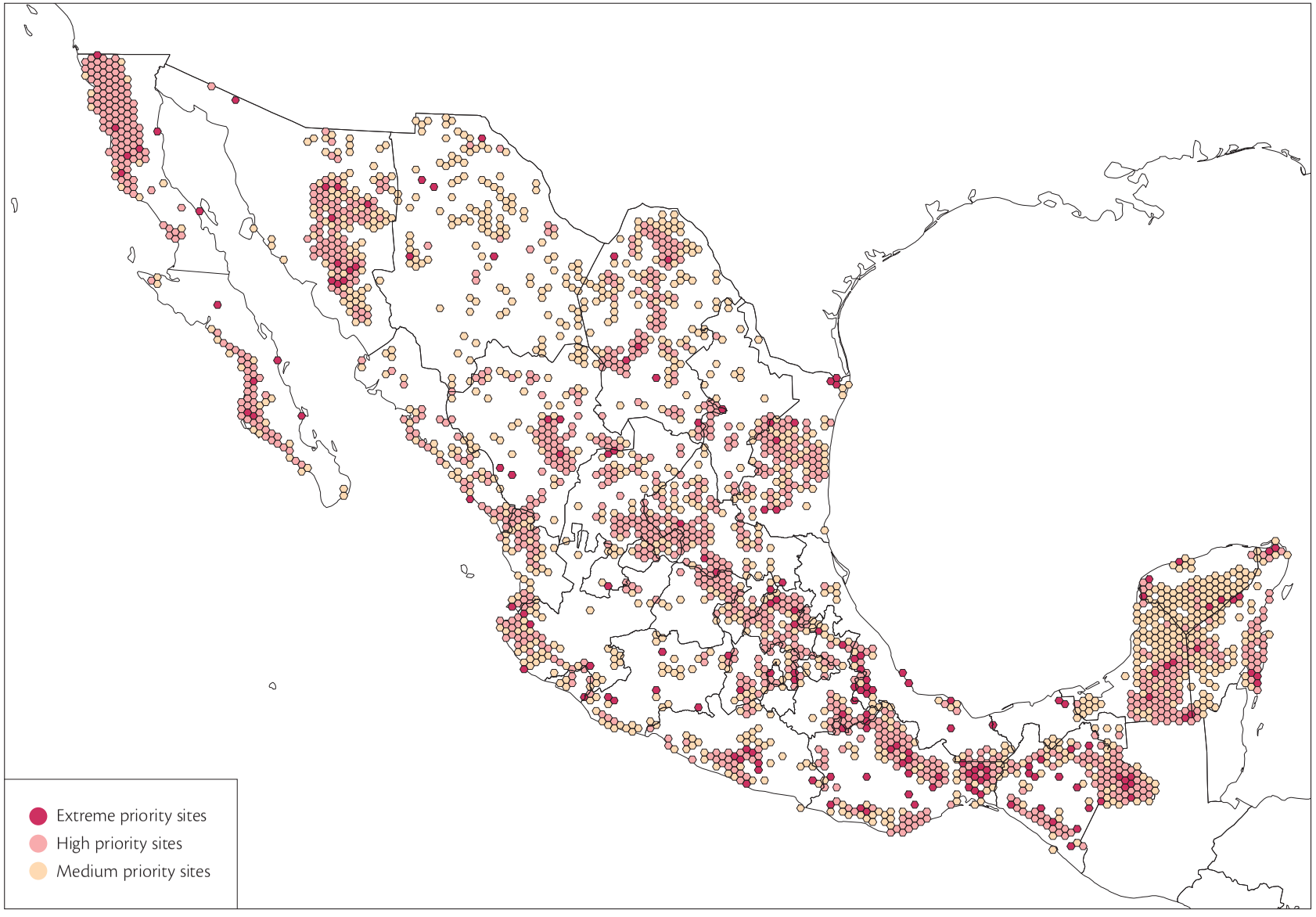
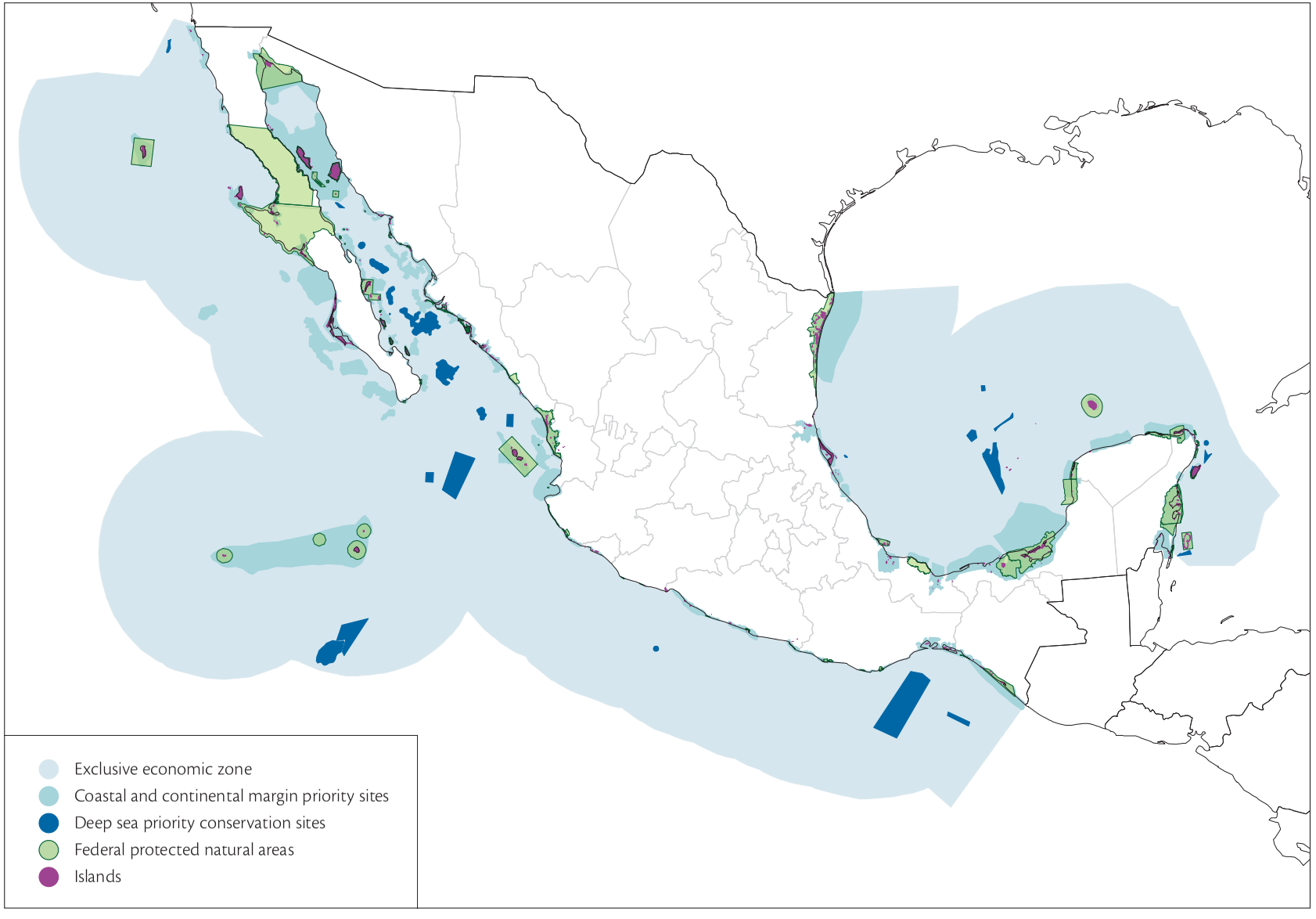


Figure 27b

Priority sites for conservation of marine biodiversity (chapter 16, Vol. II).



to consolidate efforts to conserve and sustainably manage these high-priority sites. For the first time, 29 deep sea sites, that have virtually no protection, have been identified and documented as an essential step to steer conservation efforts in these areas, unique for the biota they support and their special ecological conditions, because they represent poorly studied ecosystems and are unprotected at global and national scales.

It is vital in the immediate future to develop both ecoregional and specific strategies suited to achieving integrated planning and to consider different options for conservation, such as the establishment of protected areas, the Units for Conservation and Management of Wildlife (UMA), environmental services payments, and the role of the private efforts that carry out conservation actions. In addition, consideration of the connectivity of these areas is a key element in the planning for all systems of protected areas, and can be achieved through the creation of biological corridors, especially in the face of climate change scenarios, as well as the use and degradation of soil.

The broad horizon of conservation actions must consider the conservation and sustainable use of resources with a land-sea approach; a comprehensive perspective of the landscapes in which marine and terrestrial protected areas (under different schemes) form a network which permits the functional connectivity of ecosystems.

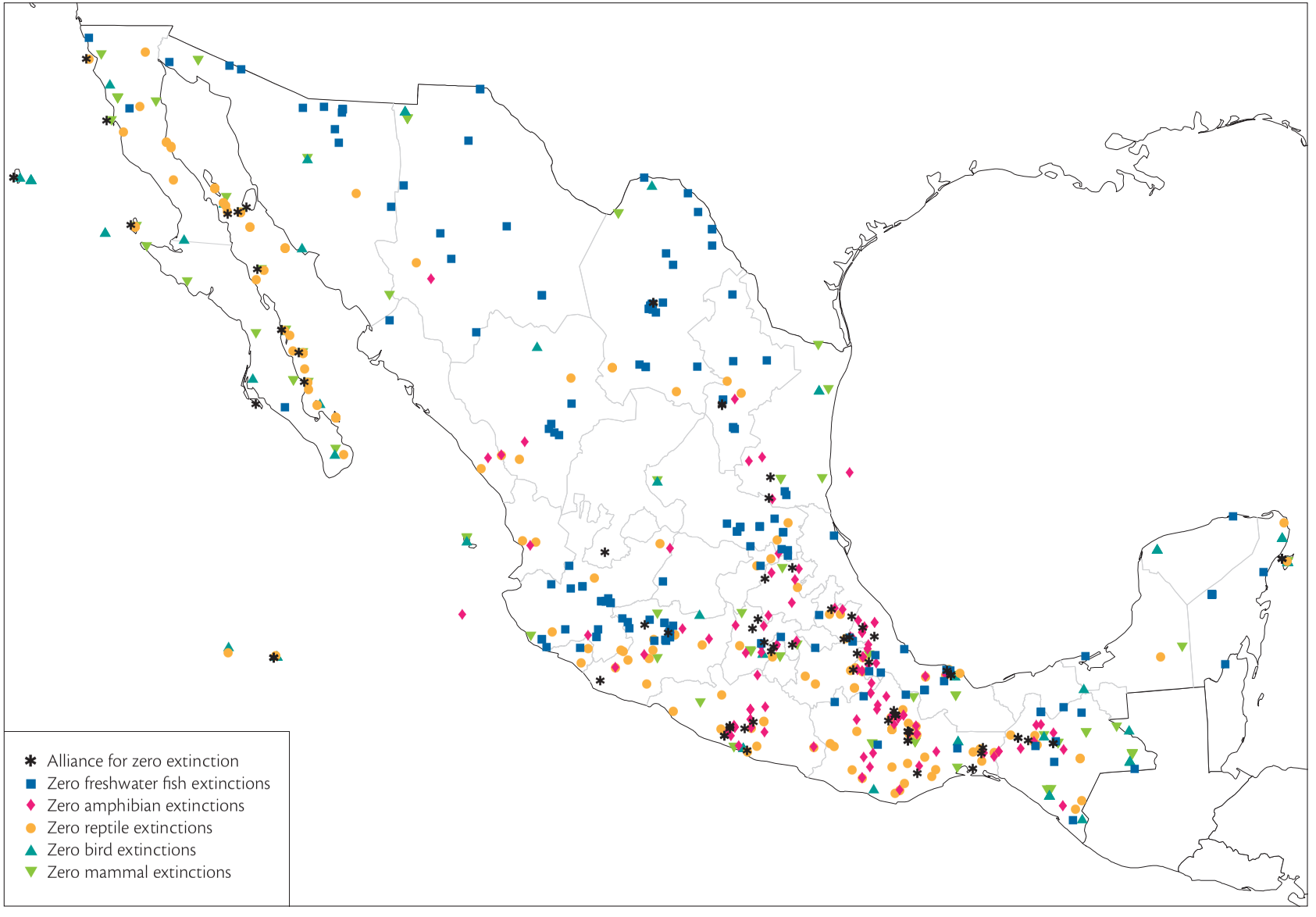
In parallel, Mexico's human, infrastructure and financial resource capacities must be considered and, it will be crucial to strengthen corresponsibility between all levels of government and the public, for strategies to be successful. It will also be vital to promote a number of actions favorable to the conservation of biodiversity based on the priorities identified by this study of natural capital. These actions should include the promotion of a new attitude within society and the productive sector towards biodiversity, the widespread adoption of an environmental culture, and a change in the current patterns of consumption in Mexico.

30 *Identification of the most endangered species or those of special ecological importance, and sites for their protection, should begin to be considered as an additional criterion of conservation with greater effectiveness in the use of time and limited economic resources.*

Due to the high biodiversity and extraordinary topographic and ecological variability of Mexico, it is necessary and desirable from the point of view of resource allocation, time and human capital, to identify in which species and regions should conservation efforts be pursued as a priority. These critical areas are relatively smaller and better identified than those corresponding to the PAs, and represent the natural distribution areas of populations of the selected species, whose conservation is threatened by anthropogenic activities. Just over half (57%) of

Figure 28

Critical sites for the conservation of mammals, birds, reptiles, amphibians, and freshwater fish of restricted distribution (chapter 14, Vol. II).



these critical areas for conservation occur within the PAs. The remaining areas require actions for their protection and, according to the International Union for Conservation of Nature (IUCN), should be considered as *Sites of zero extinctions*. Our country has the largest number of these sites, as defined by AZE (*www.zeroextinction.org*), followed by Colombia, Brazil, Indonesia and China (Fig. 28).

An additional group of organisms that require special attention are the migratory species and those with cross border populations. for reasons of international cooperation and for the biological and public health repercussions at both sides of the borders and the possible transmission of pathogens etc. Once again, the geographic location of our country explains the existence of such a large number of these species. The extent of migrations that occur within Mexican territory ranges from a few hundred kilometers to more than 10 000 km, with certain species using Mexico as a transit territory (see chapter 11 of volume II).

31 *The main strategy of environmental policy, in the promotion of conservation of ecosystems and their services, has been the establishment of a system of protected natural areas. This system, however, requires better planning and greater protection in the future.*

While protected natural areas are not considered an instrument of environmental policy by the General Law for the Ecological Equilibrium and the Protection of the Environment (LGEEPA), they are paradoxically the most well established instrument of this policy in Mexico for conserving biodiversity and the environmental services that ecosystems provide.

Overall, PAs in Mexico in 2008 (federal, state and municipal) cover 9.85% of the territorial land area, 22.7% of territorial waters, 12% of the continental shelf and 1.5% of the exclusive economic zone (figure 29, table 9).

Effective conservation of Mexican biodiversity can only be possible, with a few exceptions, in the context of achieving the sustainable use of natural capital by those populations that for generations have inhabited the territories under protection and own them.

There are very few areas of the country that have never had human population at some point in the past. Of the 900 PAs of all types (federal, state, municipal and private), 273 had human settlements in 2005, comprising a population of almost 3.5 million inhabitants, a figure that is increased by the location of certain PAs in the metropolitan areas of Mexico City and Monterrey, which together contributed with more than 850 000 inhabitants. Even though, disregarding the urban populations, PAs were inhabited in 2005 by almost 2.6 million people, equivalent to 2.5% of the total population, and 5.7% of the rural population.

Around half of the population living within these PAs fall within medium and high indices of marginalization, in 93% of the localities where PAs exist. This

Figure 29

Protected areas (PAs) for the conservation, sustainable use, and restoration of natural resources in Mexico (chapter 9, Vol. II).

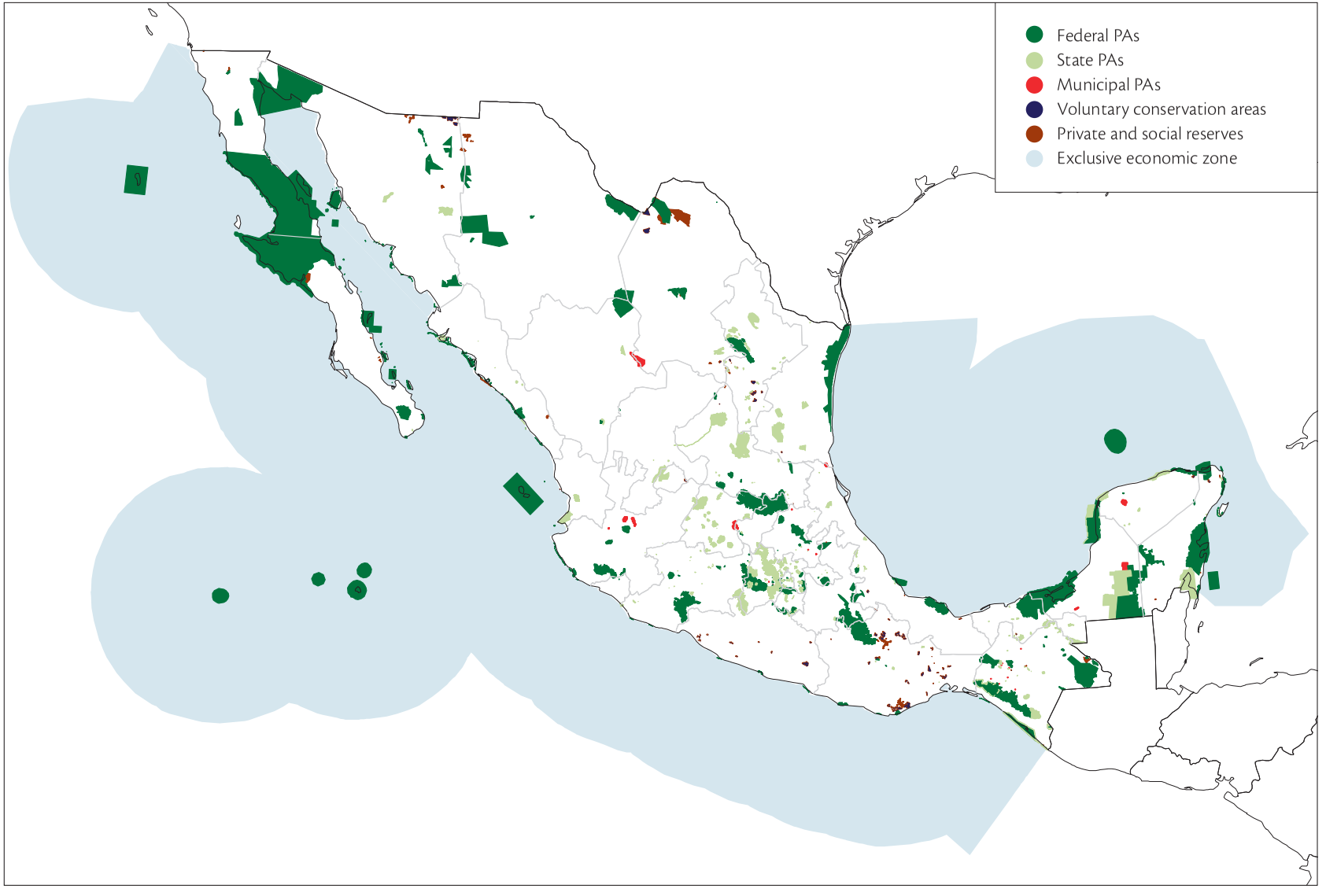


Table 9 Summary of marginalization of populations established in federal, state, municipal private and social protected natural areas in Mexico (excluding metropolitan population) (chapter 9, Vol. II)

	1995					2000			
Marginalization index	Total population	%	Towns	%	Population growth (%)	Total population	%	Towns	%
Very Low	857 880	37.81	235	4.33	−71.56	243 978	9.83	81	1.45
Low	169 212	7.46	257	4.74	328.59	725 227	29.23	297	5.33
Medium	385 690	17.00	681	12.56	−6.65	360 044	14.51	569	10.21
High	414 495	18.27	1 196	22.05	130.14	953 919	38.45	2 805	50.35
Very high	441 772	19.47	3 055	56.32	−55.19	197 962	7.98	1 819	32.65
Total	**2 269 049**	**100**	**5 424**	**100**	**9.35**	**2 481 130**	**100**	**5 571**	**100**

Note: Data include all PAs decreed by 31st August 2008; however, some of these had not been established at the date of the corresponding census or count.

situation is largely determined by the high representation of indigenous groups in these areas (table 10). In 2008, the federal, state and municipal PAs contained 3 359 agrarian or ejido units, equivalent to just over 11% of the national total.

The establishment of PAs has revolved around a social axis by not expropriating the ownership of the land when decrees were issued. Those decrees establish the type of land use in the area comprising the PA. As a result, 60% of federal PAs are social property, a little more than 20% are publicly owned, while more than 12% are under private ownership (table 11).

The National System of Protected Natural Areas (Sinap) brings together 57 of the 161 federal PAs, representing 60.5% of the total area of these areas, and one state PA. The Sinap includes a Protected Natural Areas Council, composed of representatives from the academic, industrial, social and governmental sectors, which acts as an advisory board to the Minister of the Environment. Each NA has an advisory council.

Table 10 Types of land ownership in the terrestrial portion of the federal protected areas of Mexico (chapter 9, Vol. II)

Ownership type	%
Social (*ejidos* and communities)	60.34
Private	12.01
Public	20.38
Data not available (social, private or public)	7.27
Total	**100**

Note: Data include all PAs decreed by August 31st, 2008.

Requirements for membership of the system include criteria such as the existence of a management plan of the protected area, designed in consensus with local inhabitants, a permanent budget, and trained personnel, including a director elected by the council. Although 27 of the 32 states that constitute the country have legislation concerning the creation of protected natural areas, only five of them have incorporated PAs into their systems through various legal instruments.

Some 65% of the area of federal PAs has some international recognition, as part of the World Heritage Site scheme or by inclusion as a biosphere reserve in the UNESCO Man and the Biosphere Program or the Ramsar Convention on

Table 11 Territorial coverage of Mexico's protected areas (hectares) (chapter 9, Vol. II)

	Total	Terrestrial	% of total area of Mexico	Marine
Federal PAs *excluding* VCAs	19 815 364	15 311 323	7.79	4 504 041
State and Distrito Federal PAs	3 309 418	3 071 479	1.56	237 939
Municipal PAs	124 065	124 065	0.06	0
Voluntary conservation areas (VCAs)[a]	199 146[b]	199 146[b]	0.10	0
Areas certified by the states, *at least*[a]	7 054	7 054	0.00	0
Social and private reserves, *at least*[a]	637 123	637 123	0.32	0

[a] Not superimposed on federal, state or municipal PAs.
[b] Calculated using digital cartography
Note: Data include all PAs decreed by August 31st, 2008.

Wetlands. This has been a significant transformation in the last decade. According to the categories of the World Conservation Union, only 16.75% of the area of PAs as declared at the federal level is strictly considered a reserve (e.g. national parks), since the sustainable use of natural resources is permitted in the remaining 83.25%, (e.g. in the biosphere reserves).

A significant proportion of the PAs were established in Mexico by circumstancial reasons, with little basis on scientific knowledge. Now that we have better information and awareness about the criteria that should govern the establishment of new protected areas (see chapter 16 of volume II), it is essential to ensure that relevant and reliable scientific information leads this process and that public policy decisions in this regard adhere to those criteria.

In the field of conservation action, progress may be reflected in the fact that there now exists a clear basis for prioritization, significant growth of a financially sound and effective conservation strategy implemented by the PAs, advances in conservation initiatives outside the PAs (biological corridors, *ex situ* conservation efforts and payments for environmental services), and a solid advance in the identification of gaps in knowledge and prioritization. However, the information emerging from this evaluation questions whether the steady advance in conservation actions alone is sufficient to halt or reverse the trend of deterioration of our natural capital documented here.

Industrial wooden furniture factory in Quintana Roo.

III

Although Mexico has had a long history of negative impacts on its natural capital, in recent years substantive changes and developments have occurred that have been favorable for safeguarding this capital and have laid some of the foundations for its conservation and sustainable management. However, the transition to environmental sustainability has faced serious obstacles; the changes required to achieve this goal should be broadened and consolidated. Specific objectives must be set for conservation, sustainable management and restoration, and we must achieve a valuation of biodiversity and its environmental services through, coordinated and horizontally integrated public policy actions.

The issues addressed in this study can conform a public agenda aimed at better steering directions, promoting pertinent initiatives and avoiding the repetition of past mistakes.

In order to advance in that direction, this section presents the reflections expressed in chapter 7 of volume III, which aims to be an overall assessment underpinning the key issues involved and the need to form a basic social compact. This assessment addresses the past interventions of government, which have had negative impacts on the environment and have often failed to produce any social benefits, as well as those advances of the last fifteen years that have sparked and promoted processes of rational biodiversity use which aim towards sustainability.

The chapter also gives an account of the greatest risks which, if not addressed urgently and in depth, can lead to stagnation or reversal of the progress accomplished, and even exacerbate processes which prevent achieving sustainability. Consequently, the challenges we face require the circumvention of these risks while also expanding and multiplying progress made.

It also outlines aspects of extension and consolidation of the essential changes if we want the country to advance securely towards sustainable use of biodiversity.

32 *National development has not capitalized the benefits Mexican biodiversity has to offer; instead it has rendered it subservient to economic growth.*

During the last century, and up to the 1980s, the country's development, with regard to the procurement of goods such as food, fiber, wood, etc., was based on the

extensive transformation of natural ecosystems while ignoring the consequences this would have on the natural capital. As a society, we have not reached a basic agreement on a common goal: the definition of the area of vegetation cover that the country must maintain, conserved or under sustainable management, without transformation or degradation.

The extent of vegetation cover in Mexico has been reduced by one quarter (see chapter 3 of volume III), for use in agricultural, urban and infrastructure activities, and an additional third has been compromised by the production of livestock (especially natural grasslands and xerophytic scrublands).

What could be described as "rural development", relied for decades on the encouragement of primary production activities (agriculture and livestock production), which implied the total transformation of natural ecosystems. This caused that other activities not involving the transformation of ecosystems were left behind; and thus would have retained their services and taken advantage of the many useful species of flora and fauna present in them. Some of these activities are timber and non-timber forestry, and the rational use of wildlife.

Although the rates of natural ecosystem loss have been reduced in recent decades, we continue to lose significant areas every year.

33 *Land distribution accelerated in the decade of the 1930 achieving its goal of social justice; however it had serious environmental repercussions. The owners of the natural capital did not receive for a long time the direct benefits of the appropriation of biodiversity, and public policies soon encouraged deforestation for agricultural activities.*

Notwithstanding the fundamental social justice of the land distribution programmes and the legal reforms related to land tenure, there were no mechanisms incorporating criteria of stewardship of the natural capital, and this boosted the rapid and disorderly transformation of ecosystems, utilizing land suitable only for forestry, for agricultural purposes, and both forest and agricultural land were devoted to livestock production.

In addition to this, there were frequent disputes over land use, often lasting decades, caused by a combination of factors including confusing policies, a weak legal framework, ineffective law enforcement, limited financial resources and the absence of consolidated institutions for the management and conservation of natural ecosystems. Often, the resolution to these disputes resulted in the detriment of the conserved areas—such as temperate and tropical forests—that were considered to be "idle land" and became livestock producing areas of very low carrying capacity, or temporary agricultural monocultures which culminated as unproductive grasslands, and urban or industrial developments.

The pertinence of these productive activities is not in question. The problem

lies in the disorderly manner in which the territory was occupied; on, the considerable extension of areas that have been transformed; and the productive inefficiency of many of these activities per unit area. The environmental costs, not properly valued up to now, have been enormous and have affected all members of society, particularly those under more vulnerable conditions.

The use for benefit of timber resources as well as hunting rights in forests were given, for decades, in concession to third parties and therefore the benefits of such exploitations did not directly benefit the owners of those resources neither economically or in their wellbeing. Forestry concessions ended with the reform of the 1986 Forestry Act, and hunting permits for third parties ended administratively with the establishment of the Units for Conservation and Management of Wildlife (UMA), and legally with the repeal of the Hunting Act and its replacement by the General Wildlife Law in 2000. Therefore it is not surprising that the owners of the land, receiving no economic benefit from the use of their natural capital for decades, simply transformed this, converting them into agricultural and pasture-lands.

34 *The way in which the economic growth of Mexico took place had negative consequences for the conservation of the natural capital of the nation and did not improve the wellbeing of the rural population.*

For decades, the development of the country's physical infrastructure and productive activities failed to take into account the environmental and social impacts generated by the territorial location of those activities, the extraction of raw materials and the generation and disposal of waste. Neither were these taken into account in areas of new human settlements, whose chaotic sprawl generated the phenomena of population dispersal and the expansion of regional conurbations. This unsatisfactory situation began to change when instruments of policy became available, which included the practice of environmental impact assessment, ecological landscape and settlement planning, although the application of these instruments has been the subject of constant social and economic tensions that often render environmental criteria ineffective.

Overall, the lack of vision and policies for the proper guidelines for landscape planning, occupation and management of urban settlements has resulted in:

a] a greater concentration of population living in conditions of poverty in urban areas; the rapid growth of slum areas in zones with risks of catastrophes, and urbanization at the expense of prime agricultural land and in fragile coastal areas;
b] the deep-rooted economic and social deficiency of the rural areas, compared to the rest of the country, manifested in increased vulnerability of the social

fabric, very low institutionality, absence of contractual relationships and a lack of consolidation of property rights; in short, a reduced environmental governance; and

c] an explosion of processes of direct destruction of natural capital by the rural population in areas of high environmental value, mainly tropical forests and temperate woodlands, due to the inability of the nation to achieve minimums of social wellbeing for these human groups.

35 *A period of change and substantive progress, favorable to the stewardship of natural capital, laid some of the bases for the conservation and sustainable management of the natural capital. This became obvious in improvements of the institutional structures and inter-institutional coordination, as well as in a further development of the legal and normative frameworks related to the environment.*

The creation of Semarnap, the first Ministry of the Environment, in 1994 was a substantial step toward building environmental sustainability. This began to consolidate progress towards more comprehensive approaches, in which the management of processes of conservation and biodiversity use was merged into a new institution and modern programs and instruments were designed. Within this new institution, the union of the forestry, hydrological and fisheries sectors, together with the management of environmental issues, allowed a certain amount of convergence between sectoral policies; it also incorporated a vision of sustainability in the sectoral programs and coordinated joint action to address problems that faced the several sectors.

Better organized attempts have been made in recent years at inter-institutional coordination in order to harmonize policies with other productive sectors outside Semarnat. Such efforts have provided a better understanding of the impacts that policies on food production can have on the conservation of biodiversity, and progress has been made in the improvement of rules of operation for some programs of the agricultural sector.

Perhaps the transectorial initiative most likely to produce results at present is the National Climate Change Strategy, published in 2007, which is linked to the better use and conservation of biodiversity, in measures of both adaptation and mitigation, and which should be firmly established in the Special Climate Change Program 2008-2012 (Semarnat 2009).

As for decentralization of functions, some models of wildlife management in the northern states are a good example of coordination in governmental actions.

With regard to the regulatory framework, from 1997 to the present new laws have been enacted and numerous regulations decreed governing the use and conservation of biodiversity. Unfortunately, implementation and monitoring both suf-

fer from serious shortcomings due to limited availability of financial resources and personnel of Profepa (the Federal Environmental Protection Agency), despite having had its powers and responsibilities enlarged with a new institutional structure.

36 *The country has remarkable examples of management of its natural capital which combine conservation, in a context of natural resource management, with economic viability and which have been driven in large part by the communities themselves, as owners of the natural capital.*

Protected Areas (PA) and Management Units for the Conservation of Wildlife (UMA), along with sustainable forest management (SFM) of community forest enterprises and ecotourism, have proven to be both economically viable and environmentally sound. Since these measures are carried out by the landowners, they contribute to the social cohesion and welfare of the communities themselves. These are sustainable and productive options that generate employment and income for local people who own the natural resources, and maintain the vegetation cover. These activities are still incipient: the UMAs cover 26 million hectares and SFM accounts for 6.5 million hectares and they have not yet reached their full potential, which is estimated to be around 40 and 21 million hectares, respectively. These represent the best, and perhaps the only, strategies for combining the protection of the remainder of the natural capital of the country in a satisfactory condition, with a serious contribution to the reduction of the social and economic marginality of the owners of these resources.

The legal reforms that ended concessions to third party intermediaries for the use of forest resources and wildlife — restoring rights to the legitimate landholders — have favored the conservation of natural ecosystems. The purpose of these reforms was that the owners of the land, having legal certainty about their ownership of the land and receiving economic benefits from the use of their ecosystems, do not transform these areas for agricultural activities. However, this form of sustainable management of our natural capital and provision of income for a population that comprises the 20% most marginalized of our society, has not been adequately recognized by various sectors of government, largely due to the uneven perception of environmental criteria in the public policies of each sector.

A wide range of experiences, projects and initiatives in the transformed ecosystems across the country, has shown that a productive reconversion to agriculture and fisheries, focused on better access to markets and under criteria of sustainability, can raise income, employment and productivity, controlling and mitigating negative effects on human health and the functionality of natural ecosystems, both aquatic and terrestrial. However, their full inclusion in rural development policies is dependent upon the ability of institutions to promote them, of producers to self-organize and of economic subsidies to remain in place until the conversion

becomes profitable. In this regard, legislation on fisheries and the national fishery charter have made an invaluable contribution to the gradual orientation of this activity towards environmental sustainability. However, this process has been hindered by the separation of the environmental and fisheries sectors.

37 *The ecological landscape planning of the country is a very powerful regional instrument, which has thus far been applied in an intermittent and geographically uneven manner.*

Early efforts in the environmental planning of land use, at national, regional and local scales, have shown potential for the prevention of ecological degradation processes, as well as the identification and evaluation of opportunities for regional development. These efforts enjoy legal support and show great progress on the path to the land use regulation of the country; however, their efficacy has been questioned due to a lack of agreement and convergence in actions between the productive sector, the local and federal authorities and local populations, and the disparity between the conservation interests and those of economics. In contrast, community land use planning, not considered by the law, has been more effective to date.

Other forms of land use planning are focused on watershed management and the creation of biological corridors linking areas of fragmented vegetation with protected areas to prevent an increase in their deterioration. These are approaches which lead to the gradual harmonization of policies operating within these territories. A prime example is the Mesoamerican Biological Corridor (MBC) initiative, the primary objective of which is to connect PAs, which are becoming isolated, by means of areas that are managed sustainably; conserve the ecosystems and provide income to their land owners, promoting production processes compatible with the conservation of the remaining ecosystems and the recovery and improvement of degraded areas.

38 *Economic instruments have been developed and implemented recently, which valuate environmental services; however, the impact of these is still incipient and fragmented.*

Programs aimed towards the evaluation of environmental services, mainly with regard to the water cycle, are among the most recent notable developments. Such programmes have been instrumental in the design and implementation of economic tools, like payment for environmental services, fees for access rights to protected areas, sustainable or organic product certification, or the certification of sustainably managed forest land. Some of them have had promising results, but

those experiences remain isolated or are limited in scope, and have not been incorporated into economic policies. These programmes have experienced problems of dispersion, restricted presence in the country and suffer from severe financial limitations and differences in conception and design of the operating rules of each program.

Due to their potential in the valuation of environmental services, such programs have relevance in certain areas, but they still do not represent a significant contribution to the long aspiration for certitude and stability in the rural sector; it is unfortunate, that for certain government circles, these incipient programs have generated the false perception that environmental services are adequately valued in the country and that this topic is being addressed appropriately. This fact distorts the content and hierarchy of the agenda of government actions concerning one of the fundamental problems facing sustainability in Mexico. These programs, which represent a beneficial payment for environmental services, could be reversed if adequate attention is not paid to their legal implications, appropriate conceptual support and the convenience or not of their long term maintenance.

39 *Several mechanisms have been developed for improved social participation in decision making regarding environmental issues: this is a tool that should be expanded and improved upon.*

The areas of participation of society in managing the use and conservation of biodiversity were extended since 1995 to incorporate the collective experiences of different sectors in decision making, and to combine the capabilities of each of them. A number of councils were established to assist in the forestry management of the PAs, of water management, on reforestation programs and on the recovery of endangered species, among others. Hundreds of representatives from academia, business, society, different levels of government, and Congress participate in these efforts.

These processes have meant positive gains for transparency in public management, which ensures the accountability of decision makers. However, there is not yet a concerted process in place, to guide the evolution of these institutional mechanisms, in such a way that it would allow the airing of complex processes to achieve collective solutions, socializing and collecting information and creating some degree of consensus on the conservation and sustainable use of biodiversity. Mechanisms are needed to ensure the adequate representativity of stakeholders, their co-responsibility in the management of resources and their participation in the definition, application, evaluation and amendment of policies.

40 *The transition towards environmental sustainability, despite its progress, faces serious obstacles which must be overcome.*

Various institutional inertias, and policy and regulatory inflexibilities have delayed the implementation of innovations; bureaucratic viscosity and deep-rooted resistance to change, some from professional guilds, have obstructed progress towards the fulfillment of goals by creating mechanisms of internal opposition.

Although the regulatory and control framework is sound, it suffers from serious deficiencies in law enforcement and its effectiveness is limited. In fact, despite the advances, described in theory in the regulatory framework, it is rendered almost ineffective due to the persistence of a chronic problem of scarce legislation compliance, the inconsistencies of legal norms, rules and institutional attributions relating to the management of natural capital, in addition to the scarce level of intergovernmental cooperation.

Overall, public action has failed to identify and establish the institutional mechanisms to guarantee the appropriate valuation of biodiversity and its environmental services, a necessary condition to control the main deterioration processes. This issue is represented only marginally in the government agenda, despite of the evolution attained regarding the legal dispositions.

Something similar occurs with the substantive issues of the emerging agenda of environmental transversality; i.e. the valuation of biodiversity and its environmental services has not been viewed as a central issue for which responsibility must be commonly shared throughout those sectors of the federal public administration which have the greatest territorial influence, and among the municipal, state and federal levels of government.

In contrast, there is an increasing interest and intense discussions between the more specialized and proactive members of society regarding the valuation of biodiversity and its environmental services, and it is this area of the public agenda which may give rise to concrete and viable initiatives that could become part of the government's agenda.

41 *Development policies that continue to relegate the management of biodiversity to a position of low priority ignore basic elements of national security and the future prospects of the country.*

The inefficiency of public actions has not been completely overcome, and the strategy in recent years of rural management with a *"golpe de programa"* approach (a program for every problem) has meant that public resources are dispersed and cannot translate into substantial environmental, economic or even social improvements. Some of the deficiencies are:

a] limitations and asymmetries between the legal and regulatory frameworks and the institutional domain, especially in regard to enforcement of, and compliance with, the law;
b] government actions not founded on clear rules, on programs and actions with long-term vision and with continuity in their implementation, i.e. there is no certainty necessary for rural development, and
c] the divergence between policies and instruments concerning market dynamics.

On the academic circuits, and in some government agencies, it is considered that the failure and ineffectiveness of government rural intervention tend to translate into a national security problem.

It must be borne in mind that the conservation and use of natural capital does not get resolved in the rural areas alone. This central issue of the national agenda needs to be projected towards the cities and those economic activities and markets with the greater territorial impact.

42 *Various factors, some intrinsic to the rural communities and others belonging to the national level, have weakened the structures of local governance.*

The complex problematic of biodiversity is closely linked with the rapid weakening of local rural government structures, particularly the ejido. Population, economic and cultural dynamics in the rural environment, such as immigration, aging of the population of the ejidos, remittances from emigrants, and diversification of income sources outside the scope of primary activities, among others, all have an influence in the weakening of the ejido.

The most important negative effect is the increasing loss of control over the use and occupancy of ejido land, where markets are emerging in the rental and sale of land for different purposes that result in further fragmentation of the social fabric and clear risks of environmental impact. This prevents the possibility of the regulation of conservation and use of collective resources and is, by nature, accompanied by a degradation of their culture, visions and collective practices concerning their natural resources.

A prime example of the high convergence between trends of deterioration of biodiversity and the weakening of the ejido is the phenomenon of fragmentation of areas of common use, mainly the forests and woodlands belonging to ejidos located in the southeast of Mexico. This phenomenon has been documented in some regions and it constitutes a clear violation of the agricultural and forestry legislation, minimizing the potential for conservation and promotion of sustainable production processes.

With regard to private participation in conservation, it should be noted that the various laws to control land use and occupancy offer great potential, provided that the conduction and supervision of the process is in the care of the governmental institutions responsible for the protection of the Mexican natural heritage, so this can be accompanied by institutional mechanisms of transparency and public accountability.

43 *The role of the market is of great importance in the efficacy of conservation actions and sustainable management, but this has not been considered in decisions of public environmental policies.*

Within the range of stakeholders committed to sustainability, governmental or otherwise, visions, initiatives and actions predominate which, at different forms and intensities, ignore or marginalize the determinant role of markets in the complex relationships between social systems and ecosystems. This prevents the identification and assessment of economic, social and environmental opportunities in the design and consolidation of sustainable productive projects.

Thus, efforts towards the sustainable utilization of biodiversity, far from seeking an impact on the predominant primary activities, focus on initiatives with very local and "endogenous" profiles, or in the so-called "green markets". These are positive actions in themselves, but have limitations in that they only operate in specific or collateral cases, and do not occupy a central role in the rural economies.

44 *There has been much recent emphasis on governmental transversality in the environmental agenda and on its incorporation into the economic development programs of the country; however, there is still a long way to go for this to become reality.*

The advances in cross-sectorial environmental programmes provide a basic platform to extend it into the policies and instruments related to the primary economic activities, which represent the bulk of the economy and possess well developed markets.

Our country must recognize the enormous importance of the economic and social dimensions inherent in conservation activities and, consequently that the costs and benefits of these activities must now be incorporated into the values associated with the national economy. The conservation of natural capital is not foreign to the economic logic of actions and resources dedicated to the maintenance and renewal of capital in infrastructure or industrial productivity.

In this sense, there must be an elimination of asymmetries of rural public expenditure which now concentrates on irrigated areas, with a greater support for in-

frastructure, equipment and linkage with productivity chains, while marginalizing the rest of the rural areas or only providing them with compensatory and assistential programs. Most environmental actions are associated with this latter programmes, limiting the options for sustainable utilization of the natural capital.

For these purposes it is required—among other measures—to extend and enhance the role of governmental promotion in the interaction with markets; highlighted in this respect we highlight the urgent need to assume that marginal farmers play—a key role in the future of the natural capital, and therefore as market players. Only this will allow them to change their economic strategies into profitable schemes and, in the medium term, to be independent of compensatory and assistential programs. To achieve this goal, it is essential to develop local capacities related to market access and the guarantee of their permanence.

Achieving the above situation requires comprehensive projects; stable support programs and solid regional economic projects related to the diversified use of biodiversity, or to uses that have "promising" markets, and to avoid going down the route of isolated actions. A second necessary element refers to the recognition (and taking advantage of) that it is within the scope of markets and urban settlements, where a range of agents specialized in such capabilities are located. Accordingly, it can be viewed that the most viable and effective method to bring these capabilities to the marginal farmers are the alliances or contractual relationships characterized by the establishment of a balance between contributions and benefits on both the supply and market sides.

It is imperative to initiate an effective promotion of innovation in local institutional arrangements that facilitate and crystallize concrete social agreements, to which the resource owners are central characters, establishing long-term binding contracts to ensure the consolidation of property rights, their transparency and their proper valuation and compensation.

This implies innovations in the mechanisms and forms of the government's relationship with ejidos and communities, so that it can assume binding and stable commitments, independent of changes in public spending and of those responsible for decision making.

Reforms to government action, especially in the area of beneficiaries of public spending, would seek to insert models of sustainability in the main primary activities and, in parallel, increase the access of the rural economy to the markets. The latter calls for a reform in approaches, initiatives, programs and rules of operation, and a move beyond the situation where each community is expected to develop its own market access capacity in accordance with guidelines of sustainability, towards one that directs greater effort to the creation of alliances between parties, establishes contractual relationships in the rural sector, and positively enhances interactions of communities and rural households with the markets.

45 *The changes required to achieve environmental sustainability should be expanded and consolidated. The country must set concrete goals and deadlines to achieve conservation, sustainable management and restoration of biodiversity and its environmental services. This can be achieved through regulatory, economic instruments of a market which values biodiversity and its environmental services,and the undertaking of comprehensive, coordinated and transectorial actions.*

The predominant culture in Mexico's economic development overestimated the natural capacity to withstand the impacts of economic growth and overexploitation of resources, and indeed widely imposed the idea that Mexico's natural patrimony could indefinitely support demographic and social expansion, as well as that of the infrastructure and cities. Intervention of ecosystems was seen not only as an innocuous process, but also as a necessary one. Some relevant measures were adopted at an early historic stage, such as the establishment of the national parks during the government of Lázaro Cárdenas in the early 40's. These protected those environmental services in regions of high ecological importance, but the measures were marginal and were abandoned prematurely or simply ignored.

Towards the last two decades of the 20th century, when various environmental problems such as water scarcity, soil erosion, loss of forest cover, etc., became starkly obvious, we found that for a long time the focus, institutions, production practices, laws and regulations, attitudes and values, with which Mexico had grown, had become predatory strategies that interfered irrationally with ecosystems, with no regard to their natural cycles of recovery.

In response, an environmental policy was gradually established, comprising strategies of protection and conservation which have slowly been changing the degradative patterns of biodiversity utilization. Since the early nineties, the destruction of nature is no longer seen as a justified cost of social progress and, above all, it has been realized that, for the majority of the rural sector, this destruction does not translate into substantive social advancement. The nation became aware that neither the cities could cope without healthy ecosystems because they require flows of environmental services essential for their survival.

Furthermore, the idea has emerged that the flow of environmental services provides an interface between nature and society and its demographic conglomerates, in the vision that these flows require an active counterpart that favors their maintenance. The concept of linkage between global environmental processes and biodiversity has also been established, due to the scientific knowledge concerning the services of provision, support and regulation that ecosystems render.

These changes are all still in process and it would be imprudent to argue that they have already been secured, are irreversible or are already yielding practical results. The processes of environmental deterioration continue, perhaps at a slower pace than in the past, but still with very serious consequences. Worse still, the

most severe impacts could be about to occur: it is likely that in many respects we are already exceeding the stability thresholds of various ecosystems and we are faced with possible abrupt and nonlinear changes, induced by the higher levels of vulnerability exacerbated by global phenomena, notably climate change, as the Millenium Ecosystem Assessment has stated.

The success of our vision requires understanding the particular context in which we find the rural sector and the Mexican territory in general. The majority of rural areas are subject to a contradictory transition: on one hand, demographic dispersion is maintained, and seems to increase, with the continued emergence of new settlements that expand the frontier of human occupation and on the other one sees the continued decline of the economic and population contribution of the rural sector, compared to that of the urban sector, while migration to the cities and abroad persists.

Rural depopulation is relative, and highly differentiated by region; many areas critical to the generation of environmental services are characterized by a strong presence of indigenous population whose territorial domination is not only a recognized legitimate right, but a key element for conservation, provided the patterns of social cohesion necessary for resource protection are maintained or restored.

It is important to realize that there is an ongoing cultural and generational change conducive to the transformation of visions and practices that were based on the predatory subordination of the rural sector and its biodiversity, and to an orientation towards a more balanced relationship, which can curb ecological deterioration and bring about the protection and restoration of ecosystems and their environmental functions.

Far-reaching actions are imperative towards this goal. One of these actions is that the country should achieve an image-objective of conservation and restoration, reflected in a determination throughout the nation about the extension of the country that needs to be conserved, not only through reserves and protected areas, but also by the ensemble of all available public, social and private instruments. It is necessary to resist the temptation to raise a rhetorical national agreement about conservation of biodiversity that could corrupt these efforts. The goal is to build or reform institutions, starting from our existing capabilities that will be able to achieve the image-objective of conservation and restoration. It is more viable, and in line with current initiatives, *to seek to gradually constitute social arrangements at regional, state or local scale* which envision a core of common purposes regarding the use and conservation of biodiversity.

Our country has developed in the last fifteen years a range of capacities in institutional, legal, and human capital infrastructures, providing us with a historic opportunity to consolidate the institutional channels that can enable the revaluation of biodiversity and the rural sector based on the premise that environmental services are the most important interaction between the rural and urban sectors, and to use environmental policies and their potential for transversality, with

the rest of rural policies, in order to support the role of the ejido as an entity of social cohesion and regional interaction.

The integration, coordination and transectoriality of policies related to biodiversity and the land should not only be a priority for the federal government, but also for the processes of intergovernmental concurrence and the interaction between governments and local society and, particularly, with associations of producers, landholders, communities and indigenous groups.

While the decentralization of functions of the federal government to strengthen the federated states has generated successful regional development processes, it should be taken into account that some components of biodiversity, by virtue of their character, strategic potential for development, uniqueness to Mexico, their fragility because of the threats they face, or because they have no geopolitical boundaries in their distribution, are resources that should be reserved for the jurisdiction of the State and managed under federal leadership, or at least under strict and transparent rules of concurrent management. The fact that there is no explicit policy on this issue gives rise to many tensions between the various levels of government.

If this is a collective task—as indeed it is—one more essential change will be to balance approaches and assume the protection and conservation not only as a process of command and control by taxative regulatory instruments, but through broad approaches that involve economic mechanisms through valuation processes that recognize and retribute economically the environmental functions that are to be maintained by the owners of the land and natural resources.

It is understood that the above is possible in a gradual process, involving learning of economic-environmental valuation and market adaptation and generation, all of which are already present in an incipient process of development.

In other words, in the new generation of policies to protect biodiversity and environmental services, priority should be given to the whole of society, not only to governments and their associated bureaucracies. Above all, it should be a task for those who have the rights over resources, and who should therefore obtain substantive benefits from them. One of these aims, which is central to any agreement incorporating a territorial vision, refers to the changes necessary to improve the use and occupation of the land. A toral element to these changes is the establishment of targets and commitments concerning areas of vegetation cover that require preservation, subject to guidelines of sustainable use and conservation based on the best scientific information available to us.

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Natural Capital of Mexico

In February 1992, a select group of Mexican and foreign scientists, invited by the President of Mexico at the initiative of José Sarukhán and Rodolfo Dirzo, participated in the International Meeting on the Problems of the Knowledge and Conservation of Biodiversity. At the conclusion of the meeting, and following the recommendation of the participants, who recognized the considerable progress that already existed in the country on the subject, a presidential agreement was published for the creation of the National Commission for the Knowledge and Use of Biodiversity, in March of the same year. Its mission is to promote, coordinate, support and implement activities directed towards the understanding of biological diversity and its conservation and sustainable use for the benefit of society, and to serve as a bridge between the scientific community and government decision makers.

The institution began its work nearly 18 years ago with Jorge Soberón as the Executive Secretary and a group of researchers with an academic spirit, a scientific creativity and sound vision that made a mark on CONABIO that lasts to the present.

CONABIO's work has contributed significantly to the current state of advancement and dissemination of knowledge on the biodiversity of Mexico. This work has been carried out in close collaboration with various sectors of society, mainly the Mexican scientific community, whose participation has made possible to achieve such robust results. Today, it is an institution recognized and respected internationally for the quality of its work and for its achievements in the field.

In 2004, CONABIO decided to undertake an ambitious effort to assess the status of biodiversity in the country that would include an analysis of what has happened in the recent past regarding our natural capital and possible scenarios in the future. The work began by making an extensive call to specialists in areas related to the biological and cultural diversity of Mexico, in order to gather a broad group of collaborators who could provide different approaches, knowledge and experience.

The study developed by this group of over 600 authors from very diverse institutions and organizations has been enriched and nurtured, in many aspects, by the information and knowledge compiled or generated by CONABIO.

In this sense, we can state that the publication *Natural Capital of Mexico,* now presented as the culmination of this study, is the result of the work of those researchers who participated, and of those who have formed part of this National Commission.

It has been very satisfying for CONABIO to have benefited from the kind collaboration of this broad and valuable group and we are deeply grateful for their generous efforts and dedication in carrying out the work. It is a matter of pride for those who work in this institution to have contributed with the authors so that Mexico can possess a work of such magnitude which we are certain will be of great significance for our nation.

Ana Luisa Guzmán
Former Executive Secretary of CONABIO (April 2005 - February 2010)

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