Alfredo Ortega-Rubio *Editor*

Mexican Natural Resources Management and Biodiversity Conservation

Recent Case Studies

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Foreword

The reader has in his hands a remarkable book. The authors are undoubtedly professionals of extraordinary academic, scientific, and institutional prestige. They have managed, with a demanding coordination effort, to capture the multiple dimensions presented by the management of natural resources and the conservation of biodiversity in Mexico. In addition, this book offers the advantage that the general aspects are accompanied by case studies that are quite illustrative.

One of the most outstanding characteristics of this compendium is that all its authors have submerged themselves in the complexity of the management of natural resources. In the different chapters, the reader will find how the institutions face the fantastic challenges that the Mexican society has bequeath them with respect to preserving its natural resources. In addition, the book covers how the users of the resources interpret their role.

Moreover, in fact, the management of natural resources and the conservation of biodiversity are issues that affect, on the one hand, the need for a new way of looking at and interpreting reality. On the other, they have a direct impact on the public sphere of action.

On the first issue, it is necessary to recognize that the exclusively natural habitats in the twenty-first century are essentially nonexistent. The human being is present fully, directly and indirectly, in all Mexican ecosystems. For this reason, the expression "socio-ecological" systems becomes increasingly valid in scientific language (and is likely to sooner, or later, become part of the common lexicon). Because it is not just about the number of people in this country, which is considerable, there are almost 120 million inhabitants indicated by INEGI for 2015 (National Institute of Statistics and Geography). The truly central question is the technical capacity of all these people to affect or intervene, through their respective ways of organizing themselves, in any ecosystem or place in the Mexican geography.

With regard to the second issue, the framing of policy in the public sphere of action, it can be affirmed that it should be approached as a specific issue to which a public policy would correspond. In the construction of this public policy, some basic elements should be considered: regulations, institutions, allocation of responsibilities, coordination and cooperation mechanisms, formulation of plans and programs as instruments, training of managers, generation of information and knowledge, allocation of resources, education for sustainability, and participation of citizens and companies. Probably this is the broad view that the new governance model demands.

It seems reasonable to think that for the subject that concerns us, simple and one-dimensional visions are behind us (less accepted are uni-disciplinary). In addition, it is necessary to incorporate a reasonable degree of uncertainty regarding the future. Everything points to thinking that the management of natural resources is not, strictly speaking, just the administration of animals and plants in a physical context governed by natural processes. We actually must also include management of the human activities that affect those natural resources, in such a manner to influence social behavior when they produce disturbances or negative impacts.

In addition, in the middle of these two approaches is the interpretation of reality as a "socio-ecological" system, on the one hand, and that of seeking a governance model for that system, on the other. This is where we will find ourselves today. The different conceptual frameworks, in this case those referring to ecosystems and those that concern governance, should be tackled directly. Sustainability, which can be interpreted as the ability to survive, will be the central axis of discourse in the coming decades. In addition, the main task will be to integrate from the conceptual, methodological, and practical application point of view the two approaches described above.

In summary, due to the contents of this book and its reference to other important works carried out in Mexico in regard to conservation of natural resources, the consequences of this work will reverberate in Mexico. There is no doubt. Nevertheless, and this should be emphasized that, the rest of Latin American countries are grappling with the same issues, because conservation of "socio-ecological" systems is a task that transcends all national states. This is another reason why this book deserves maximum diffusion.

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Preface

To date in Mexico many splendid books have been written about biodiversity conservation of this megadiverse country from a conceptual point of view. That is why for this book we set out to have a different objective. Unlike most of the earlier studies, this work focuses on analyzing the relationship between the management of natural resources and biodiversity conservation at the level of the local communities living in these places. In addition, the emphasis of this work is on the analysis of case studies developed with a multidisciplinary approach in order to develop practical recommendations for biodiversity conservation in Mexico. These recommendations, it is hoped, can be extrapolated, given its immediate usefulness, to other Latin American countries.

A peculiarity of our Latin American countries is that conservation of biodiversity cannot be given by legal decree due to urgent social and economic needs that prevail. In addition, many Latin American countries also have very fragile legal system for law enforcement. Thus, the only way that the provisions established for the conservation of biodiversity to be truly effective is to be based on strong community support, especially by the people living in the area. That is, the people themselves, if they are able to receive improvements in their standard of living linked to the conservation of the resources, become the champions of conservation.

In Mexico, it is not possible to protect the yet still rich biodiversity based on only issuing legal decrees by government authorities. In our country, the effective protection of biodiversity can only be achieved through sustainable management of natural resources involving the actual human inhabitants of the communities that have settled there. Some having settled hundreds of years ago.

Protection of natural resources of course implies conservation. However, who will best conserve these natural resources? Will government officials writing the laws in Mexico City, far removed from the realities that exist in the actual location of these resources, be good and adequate custodians? We believe that local populace who find a real and direct benefit from their sustainable use of the natural resources will be far better custodians. This book emphasizes this approach through the presentation of case studies where the relationship between this binomial, i.e., management/conservation, is described.

The book also provides another benefit, researchers working in institutions located outside of Mexico City have written most of the chapters. These researchers provide a unique perspective of conservation of natural resources at the ground roots local level, since they work directly with the people who live near important natural resources. This also is a distinguishing feature of this work. Although local researchers wrote this book, it is intended for an international audience.

The book is organized into three sections.

In the first, theoretical aspects of law, society, and sustainability are studied, analyzing aspects such as socio-environmental conservation aspects of rural communities (Pinkus-Rendon et al.), phylogenetic studies and legal status of key species (Blazquez et al.), public policies and biodiversity conservation in Mexico (Muñoz et al.), and laws regarding intellectual property and biodiversity conservation in Mexico (Beltrán-Morales et al.).

For example, Galindo-Gonzalez and Rivera-Arriaga described how protected areas in Mexico could be one of the instruments for implementing Nagoya Protocol and Aichi Goals, and how such task requires strengthening capacities at several levels of the Mexican government, especially at each one of the natural protected area (NPA) managerial offices. They assessed the institutional capacity for implementing those instruments and offer specific recommendations.

Jimenez Sierra et al. analyzed if current actions for conservation in Mexico are enough up to this date, because there is a wide variety of isolated and poorly integrated actions designed to conserve the biological diversity of Mexico. This lack of cohesion leads to investment actions of limited government resources into programs that are unlikely to succeed over the long term. In this chapter, a conceptual framework is introduced where specific actions are related to each other on the basis of the risks that can lead to a specific population to an extinction vortex.

Alfonso Aguirre-Muñoz et al. analyzed the environmental conservation, natural resources management, and government federal civil service in Mexico over the last 20 years. They found that the incipient Mexican democracy is unfolding, since new institutions have been created accordingly to attend to the new issues and realities. An important part has been the creation of institutions to attend to the needs of the environmental sector. However, the institutionalization process is still struggling to achieve a strong foundation, even at the federal government level. To better understand the dynamics of public management and policies in regard to environmental conservation and natural resource governance in Mexico, a detailed examination of the public functionaries' trajectories during the last two decades is presented, and an analysis about the factors driving is advanced.

In the second section, conservation and sustainability examples are described in different ecosystems, as well as its productive uses. Issues addressed among others are conservation of rural ecological systems (Pinkus-Rendon et al.), scientific conservation reserves (Gomez Barrero et al.), coastal ecosystems (Azuz-Adeath and Cuevas), artisanal fishing communities (Rodríguez Quiroz et al.), and the development of power lines (Zúñiga-Gutierrez-Perez Rubio and Veneranda). For example, Daniel Torres-Orozco et al. analyzed the forgotten social issues for achieving long-term conservation in protected areas, because Mexican protected areas are planned mainly by considering the biology of the threatened species or environments. This perspective usually assumes that the main threat is the unsustainable habits of the local villagers and that it is appropriate to exclude them from the decision-making processes. This chapter also introduces some socio-ecological frameworks, such as environmental governance, the conservation psychology, and the marketing conservation, aiming to complement and improve the long-term efficiency of the natural protected areas.

Gómez-Barrero et al. analyzed two successful experiences in promoting scientific research in Mexican conservation biology, describing the development of two private projects that promote and support scientific research in conservation biology. The first project is based on the Ecological Reserve "El Edén" (North of Quintana Roo, México). It aims to explain more than 20 years of experiences in a private field research station and natural protected area dedicated to support scientific research for the acquisition of knowledge and management of biodiversity. The second project elucidates 10 years of experiences of a project called "Por Amor al Planeta," which endorses the efforts of Mexican scientific researchers in the field of biological conservation in Mexico, specifically in natural protected areas.

Finally, the third section focuses on conservation studies of natural protected areas. For example, socioeconomic criteria were proposed to be considered before issuing by law new protected areas (Breceda et al.). Another chapter highlights the value of economic benefits of some uses in natural protected areas such as ecotourism (Lauterio Martinez et al.) versus other activities such as fishing (Olmos Martinez et al.). In addition, biodiversity of some protected ecosystems is described regarding swamps (Barba-Macias et al) and dry deciduous forest (Argumedo-Evans et al.).

For instance, Alba Gaméz et al. analyzed community adaptation of climate change and biodiversity conservation in natural protected areas at El Vizcaíno Biosphere Reserve. This reserve is one of the largest natural protected areas (NPA) in the country, and it is currently subject to pressure from climate and economic change, which increases the vulnerability of ecosystems and human communities. They found that social participation is essential for biodiversity conservation and show the need to increase knowledge on climate change issues and to strengthen institutional and legal capacities to facilitate the implementation and monitoring of adaptation actions.

We hope that the chapters in this book are potentially useful and you will enjoy reading.

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Part I
Public Policies

Chapter 1
Biodiversity Conservation in Mexico: Assessing the Institutional Capacity for Implementing Nagoya Protocol and Aichi Targets

Jesús Darío Galindo-González and Evelia Rivera-Arriaga

Abstract This chapter is based on a research project for evaluating the effectiveness of the management capacity of two natural protected areas (NPAs) of the coastal zone of Campeche, Mexico: the Special Protected Area of Flora and Fauna of Laguna de Términos (LT), decreed on September 24, 1994, and the Biosphere Reserve of Los Petenes (LP), decreed on April 22, 1999. Considering various management elements, as well as public policies, and the institutional capacity for both NPAs, we assessed the opportunities, strengths, weaknesses and threats for implementing the Nagoya Protocol and the Aichi Targets. Given the fact that both NPAs were decreed 23 and 18 years ago, respectively, with the help of the federal government with the assistance and consent of both the state of Campeche and the municipal governments, it was expected to find a suitable scenario for implementing actions and strategies to be built upon previous ones, which would have been directed to preserve biodiversity and avoid its loss. However, the reality was completely different, and we found that there is plenty of room for improvement and capacity building in a coordinated fashion and from an integrated coastal management perspective.

Keywords Coastal protected areas · Conservation policies · Integrated conservation and development projects · Conservation effectiveness

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1.1 Introduction

In Mexico, as in worldwide (Gurney et al. 2014), the best strategy for biodiversity conservation is the decree of a NPA. By law, a NPA is considered to the Mexican Constitution in its Article 27 that supports the creation and management of NPAs, as well as the General Law for Environmental Protection (GLEP) that is the baseline of the conservation and protection environmental policy in Mexico. Each one of the NPAs embraces tangible and intangible elements that compose the matrix for sustaining social welfare and environmental systems. Considering the place of Mexico at the international scenario as a megadiverse country, it is very important to underline that almost half of the NPA national system has presence of one or more indigenous groups. Therefore, each one of the NPA contains the ability to preserve both elements, known as the biocultural heritage (Boege 2009).

NPAs are also a public good that society assumes as common property (Quadri 2006). Thus, it is paramount to ensure a proper management by the government that should seek biodiversity conservation, in addition to the public good through correct policies that guarantee the quality, functions and structure of the ecosystems during time (Article 3 of GLEP's regulations). Therefore, we may assume that any NPA is a public environmental policy tool for biodiversity conservation and sustainable development. This is the driver that is stated in the National Development Programme (2013–2018) in its strategic axis "México Próspero". So, as any public policy, NPAs are subjected to audits to make sure that budget was well spent, goals were reached, and objectives were fulfilled.

The government institution in charge of the NPAs is the National Commission for NPAs (CNPA) that depends on the Ministry of the Environment. The CNPA is responsible for the management, the design and the implementation of all the NPAs' management plans and, at the same time, responds to the transparency and accountability bureau regarding the annual operation plan (AOP) from each one of the NPAs. It is important to notice that, in a number of times, strategies and policies should embrace a larger area than the polygonal of the NPA, because they are considered as open systems (Maass et al. 2010) where energy and matter trespass the administrative borders established per NPA. This is very easy to recognize in all the downstream regions (Dudley and Stolton 2003) as LT since it is part of the Grijalva-Usumacinta rivers' watershed that extends its origins to Guatemala and the state of Chiapas in Mexico.

In Mexico, NPA's goals are to convey integrated conservation and development strategies within each management plan, the activities and actions are cloistered especially in the implementation of integrated conservation and development projects (ICDPs). Several authors (Ribaudo 2008; Newmark and Hough 2000; Fletcher 2012; Hughes and Flintan 2001; Alpert 1996; Winkler 2007) acknowledge the positive impact that ICDPs bring to local communities and indigenous peoples, mainly in the tropical regions and in developing countries. The effectiveness of the ICDPs would depend on the level of understanding and reconciliation of the conservation purposes with the local capacities and the needs and aims of the community. Also, effectiveness is linked to the proven capacity for designing, implementation and results and outcome assessment.

Mexico has signed and acknowledged its commitment to the Convention on Biological Diversity (CBD) since entering into force on May 3, 1993. The CBD has three objectives: (a) the conservation of biological diversity, (b) the sustainable use of its components and (c) the fair and equitable sharing of benefits arising from the utilization of genetic resources. On the other hand, the Nagoya Protocol on access to genetic resources and the fair and equitable sharing of benefits arising from their utilization to the CBD was adopted on October 29, 2010. The Protocol *provides a strong basis for legal certainty and transparency for both providers and users of genetic resources. And at the same time, it stressed specific obligations to support compliance with domestic legislation and regulatory requirements of the country providing genetic resources. Moreover, there are now contractual obligations that are reflected in mutually agreed terms for both provider and user/buyer to ensuring the sharing of benefits; as well as access to traditional knowledge held by indigenous and local communities when it is associated with genetic resources. By strengthening the opportunities for fair and equitable sharing of benefits from their use, the Protocol will create incentives to conserve biological diversity, sustainably use its components, and further enhance the contribution of biological diversity to sustainable development and human well-being* (Booklet of the Nagoya Protocol on Access and Benefit sharing, 2011).

It is evident that the Nagoya Protocol has provided higher legal and accountability certainty to both natural resources, providers and users, setting the parameters for (1) safe, equitable and fair conditions for accessing genetic resources and traditional knowledge and (2) fair and equitable benefit share mechanisms for the use and access of genetic resources and traditional knowledge. These parameters should be met through legal and institutional strategies and mechanisms at domestic level. Mexico has to show due diligence to create the conditions to fulfil commitments and take care of the three biodiversity levels – ecosystems, species and genes – and, at the same time, take into consideration the ancestral and traditional knowledge of local indigenous communities related to that biodiversity.

In addition, Mexico signed the Strategic Plan for Biodiversity 2011–2020 and the 20 Aichi Targets arranged in 5 strategic objectives, “Living in Harmony with Nature”, which is a 10-year framework for action by all countries and stakeholders to save biodiversity and enhance its benefits for people. Biological diversity underpins ecosystem functioning and the provision of ecosystem services essential for human well-being. It provides for food security, human health and the provision of clean air and water; it contributes to local livelihoods, and economic development, and is essential for the achievement of the sustainable development goals, including poverty and hunger reduction, responsible consumption and production, climate action and life below water and life on land conservation. In addition, it is a central component of many belief systems, worldviews and identities. Yet despite its fundamental importance, biodiversity continues to be lost. It is against this backdrop that the Parties to the Convention on Biological Diversity, in 2010 in Nagoya, Japan, adopted the Strategic Plan for Biodiversity 2011–2020 with the purpose of inspiring broad-based action in support of biodiversity over the next decade by all countries and stakeholders. In recognition of the urgent need for action, the United Nations General Assembly has also declared 2011–2020 as the United Nations Decade on Biodiversity.

The Aichi Targets are contained in five strategic goals (CBD 2010):

- Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society.
  - Target 1: By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.
  - Target 2: By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems
  - Target 3: By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio-economic conditions.
  - Target 4: By 2020, at the latest, governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.
- Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use.
  - Target 5: By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.
  - Target 6: By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally applying ecosystem-based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species, and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.
  - Target 7: By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.
  - Target 8: By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.
  - Target 9: By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.

  - Target 10: By 2015, the multiple anthropogenic pressures on coral reefs and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.

- Strategic Goal C: Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity.

  - Target 11: By 2020, at least 17% of terrestrial and inland water and 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures and integrated into the wider landscapes and seascapes.
  - Target 12: By 2020 the extinction of known threatened species has been prevented, and their conservation status, particularly of those most in decline, has been improved and sustained.
  - Target 13: By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.

- Strategic Goal D: Enhance the benefits to all from biodiversity and ecosystem services.

  - Target 14: By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being are restored and safeguarded, taking into account the needs of women, indigenous and local communities and the poor and vulnerable.
  - Target 15: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks have been enhanced, through conservation and restoration, including restoration of at least 15% of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.
  - Target 16: By 2015, the Nagoya Protocol on access to genetic resources and the fair and equitable sharing of benefits arising from their utilization is in force and operational, consistent with national legislation.

- Strategic Goal E: Enhance implementation through participatory planning, knowledge management and capacity building

  - Target 17: By 2015 each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan.
  - Target 18: By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obliga-

tions, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels.

- Target 19: By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends and the consequences of its loss are improved, widely shared and transferred and applied.
- Target 20: By 2020, at the latest, the mobilization of financial resources for effectively implementing the Strategic Plan for Biodiversity 2011–2020 from all sources, and in accordance with the consolidated and agreed process in the strategy for resource mobilization, should increase substantially from the current levels. This target will be subject to changes contingent to resource needs assessments to be developed and reported by Parties.

From those 20 targets, 17 should be reached by 2020; however, target 10 (second objective) and targets 16 and 17 (fifth objective) should have been reached by 2015. Considering the difficulties and obstacles that Mexico has to overcome to fulfil the CBD and the Nagoya Protocol (NP) as well as the Aichi Targets (AT), this research considered that the best opportunity that Mexico has to comply with all the commitments is through NPAs. Therefore, the objective of this chapter is to assess the effectiveness of the CNPA to implement the NP and AT.

1.1.1 Study Area

Two thirds of the coastal zone of Campeche is protected by the NPAs of LT and LP (Fig. 1.1). Laguna de Terminos is located at the southern coast and comprehends more than 706,000 ha covering parts of the coasts of three municipalities: Carmen, Champotón and a portion of the riverine zone of Palizada. Land tenure embraces three types: private property (23%), ejidal property (13%) and federal property (64%). It is linked ecologically by the wetlands of Pantanos de Centla reservoir that are part of the Grijalva-Usumacinta estuarine delta, pouring to Laguna de Terminos 115.5 thousand million of cubic metres per year (CONAGUA 2012) and becoming the second largest freshwater input to the Gulf of Mexico after the Mississippi River.

The LT ecosystems comprehend microalgae, sea grasses, mangroves, tropical forests, marshes, grazing lands and savannas. According to the management plan of this NPA, it accounts 374 species of marine and land flora species and 1468 marine and land fauna species. From those, 89 species are under any risk or in danger category, such as the marine turtles *Eretmochelys imbricata* and *Chelonia mydas*, the jabiru stork (*Jabiru mycteria*) and the manatee (*Trichechus manatus manatus*), among many others.

Productive activities performed inside the LT area or nearby it by local people are fisheries, agriculture and livestock. But the largest and more important activity is oil and gas production, which has been the economic trigger for development in the region. Having discovered the first marine well in the early 1970s produced a

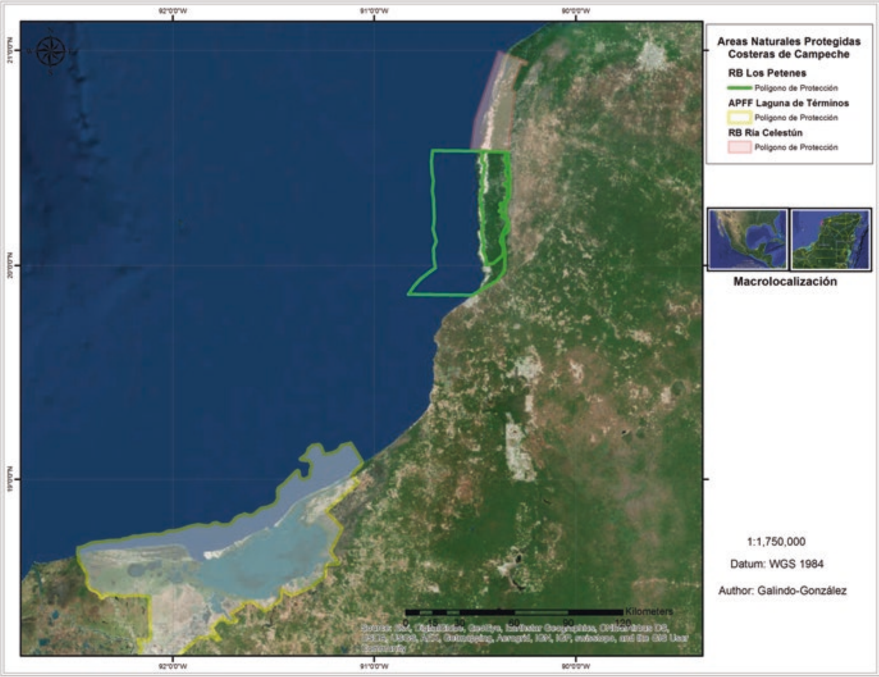

Fig. 1.1 Study area. (Source: Galindo González with information from CONANP 2015)

Table 1.1 Towns located in LT

Town	Total population	Individual households
Atasta	2535	624
Isla Aguada	6204	1642
Ciudad del Carmen	169,466	44,375
Nuevo Progreso	4851	1241
San Antonio Cárdenas	4206	1077
Sabancuy	7286	1818
Palizada	3089	867

Source: Galindo-González 2016 with information from INEGI (2010)

major shift in the economic activities, switching the profitable pink shrimp fisheries for the oil- and gas-related activities. This economic buoyancy attracted many people, and the increment of the population during the first decade of the 2000 reached up to 34.5% (INEGI 2010). The region reached more than 250,000 people distributed into seven largest towns with more than 2.5 thousand people (Table 1.1).

Los Petenes was decreed as a Biosphere Reserve with 282.9 thousand hectares including the extension of 12 nautical miles as for the territorial sea included in its

Table 1.2 Towns located in LP

Town	Total population	Individual households
Pomuch	8694	2132
Nunkiní	5859	1346
Santa Cruz Ex-Hacienda	1255	299
Imí	1227	297
Hampolol	1123	268
Bethania	984	251
San Francisco Kobén	1045	247
Pucnachén	865	201
Chunkanán	885	197
Chemblás	517	127
Zodzil	485	115
Concepción	351	95
San Nicolás	369	88
San Agustín Chunhuás	401	84
Santa María	236	58
Santa Rosa	181	51
Xkuncheil	95	26

Source: Galindo-González 2016 with information from INEGI (2010)
Here there is no accounted Campeche's locality population because there were no CNPA activities registered between 2010 and 2015

protected area. LP comprehends a coastal strip that includes the coastal zones of four municipalities: Campeche, Tenabo, Hecelchakan and Calkini; therefore, land tenure covers 5.2% private, 20.3% is ejidal, and 74.5% is federal. There is only one small fishermen village inside the NPA; the neighbour towns are outside the NPA area. LP shares the same type of ecosystems to the northern part of the state with the neighbour state of Yucatan. A petén is a specific type of island with taller vegetation that is currently formed by trees and palms, that takes advantage of an elevation of the soil and available freshwater source and that is surrounded by grass type and marsh vegetation. The management plan reports 16 species in risk, but it is important to say that is a very well-conserved NPA.

Productive activities performed within the NPA are the following: fisheries, illegal hunting, illegal logging and subsistence agriculture, and lately, octopus and sea cucumber fishing and fly fishing are major job activities for locals, which may represent more than a million US dollars in revenues. Most of them are Mayan descendants and use local resources for living. The lack of employment sources is reflected in the high degree of marginalization presented by 18 of the localities (CONAPO 2010). In this NPA the localities could be considered as rural due to their low population (Table 1.2).

Around 20 years ago, both NPAs were decreed, and natural resources and ecosystems have been under a huge stress that has resulted in important impacts and biodiversity and ecosystem loss. A major problem is that the CNPA has not got the accurate status quo of the biodiversity nor ecosystems in each one of these two NPAs nor had measured the results caused by the policies implemented nor the interventions executed. Any authority outside the CNPA has assessed the work of any of the NPA management offices, nor the management plans have been reviewed according to the procedures appointed by the law (Rivera 2011). The only evaluations ever applied by the CNPA have been conveyed to projects funded by external sources, which target the products not the results nor the impacts derived from them (Bonnefoy 2005).

On the other hand, assessments applied to the implementation of the NP and the AT have been to qualify the advances that each country has reached according to the NP framework, and the legal issues that those countries are encountering (Ribadeneira 2014). Moreover, the assessments carried out for the AT are based on the implementation analysis of other conservation and sustainable development programmes that somehow concern the ATs (Bodin et al. 2014; Osti et al. 2014). However, the importance of assessing the ICDPs of each of the NPAs according to each of their management programme is to verify the level of observation of the following points:

1. Effects on the ecosystems and biodiversity conservation
2. Level of alterations of the traditional means of living (Moser 2005; Lampis 2009)
3. Equity of the distribution of benefits
4. Level of involvement and participation of the local communities for decision-making processes (Znajda 2014)
5. Accountability and transparency of the efficiency, effectiveness and efficacy of the implementation of the budget

The aims of the research project and of this chapter are to (1) assess the performance by results of each one of the NPAs and (2) identify the opportunity to implement the NP and the AT in these NPAs.

1.1.2 Background

To this day, Mexico encloses 182 NPAs supervised by the CNPA, and 72 of them are located in the coastal and/or marine zones. The state of Campeche has got three of these coastal NPAs that have not passed through any assessment. The CNPA holds the Information, Monitoring, and Evaluation System for Conservation (IMESC); and applies the framework of the IUCN elaborated by Hockings et al. (2000) that contains three components to be evaluated: (1) suitability of the NPA design, (2) properness of the management processes and systems and (3) flawlessness to reach the NPA objectives. Under these components, the NPA assessment should contemplate (1) context and current situation, (2) planning, (3) resources, (4) processes, (5) products and (6) impacts. At the same time, Pomeroy et al. (2006)

suggest that any NPA effectiveness and performance assessment should include the indicators used during the management of this particular NPA.

In China, Lü et al. (2003) applied a holistic evaluation that contemplated level of education, poverty and local governance, together with the habitat health. In Mexico, Rivera (2011) evaluated the effectiveness of the marine protected areas through the IUCN framework and proposed an evaluation structure that contemplated the particulars of the NP, as well as the institutional capacity of the management office of the NPA. In addition, Mistry (2010) evaluated the viability and abilities within the local communities, whereas Winkler (2007) proposed an analysis using the bioeconomic system with an econometric model with a comparison of the forestall soil versus agriculture use and the waterfowl hunt, among others trying to find the equilibrium point of the system. Weber et al. (2011) evaluated everything, from the improvements of the welfare per home to the work conditions of the people in monetary terms.

Institutional capacities have been analysed by Östrom (2005) from the multidisciplinary efforts that were made considering policy, natural science, economy, anthropology and so on to analyse the relationships of the institutions with the individuals. The occurrence of this type of analysis has got diverse applications in different sectors, such as agriculture, forests fostered by government institutions (Oszlak & Orellana 2000; PNUD 2010) as well as a water management (Breeveld et al. 2013) and common resources (Östrom 2010), among others.

1.2 Methodology

Information from governmental institutions, especially from the CNPA, was collected, as well as from the environmental ministry, fisheries ministry, rural development ministry, economy ministry and social development ministry. Some of this information was found published in their official digital websites; however, some had to be asked through the transparency tools that compel those institutions to grant any public information requested. At the same time, field trips were conducted to apply semi-structured interviews to users and non-users of both NPAs, as well as the heads of the management of NPA offices and some officials of the CNPA. The quantity and type of the informants interviewed were determined through a theoretical sample that is based on the information theory (Hernández 2014), where representativeness and selection of new informants are based on the new inputs and ideas up to the saturation point, where data were the same and did not contribute with anything new from previous interviews (Glaser and Strauss 1967; Patton 1990; Hernández 2014).

Here it is important to stress out that the total staff of the NPAs are no larger than five individuals in LT and four in LP. So, interviews were applied to four members of the staff in LT and two from LP. Another point that is important related to the users. NPAs work with social organized groups that have representatives, such as fishermen or handcraft groups. Therefore, interviews were applied to two non-users

Table 1.3 Framework for the evaluation of the NPA performance

Management elements (Hockings et al. 2006)	Components
Context – Where management is located?	Important ecosystemic elements, cultural and socio-economic characteristics
Planning – Where is this going? Which are the employed planning tools?	Management plan; annual operating plan; size and form of the NPA
Inputs – What are the required actives?	Institutional capacity of the management plan office (capital: humane, physical, budgetary and social); scientific research
Processes – How does management developed?	Governance, communication and education programme, subsidized programme
Products – Which are the management products?	NGOs that participate in conservation; tools for fostering conservation
Results – What have been the achievements? Which have been the impacts generated by this intervention?	Status of the CNPA within the society; perception and attitude of the society; state of the NPA conservation (the species in risk status, use of vegetation and soil changed)

Source: modified from Hockings et al. (2006)

and five types of users in LT and four non-users and five users in LP, academic researchers included. Because of this diversity, there were three different interview formats to take advantage of the quantity and quality of information each may provide.

Considering the data, two categories were created according to Strauss and Corbin (2002) to form clusters with similar successes, objects, actions and interactions, which facilitate the interpretation process, analysis and discussion construction (Rodríguez and Valldeoriola 2009). A selective codification was applied for relating different categories with the central category (Giménez 2007), which help to analyse the effectiveness management of the NPAs. Also, we established a triangulation linkage between the material provided through interviews and the data from other sources of information (official information and about the theoretical framework) (Cabrera 2005). From beginning to end of this comparative process, it was possible to validate the information coming from different sources and, at the same time, construct the discussion and analysis to assess the NPAs' effectiveness for NP and AT implementation.

To evaluate the effectiveness of the NPAs, Hockings framework was used with its six evaluation elements, as follows in Table 1.3.

Results found were described encompassing each one of the elements and components, and at the same time, it was important to present a summary chart detailing graphically each one of the elements from each NPA, using as baseline the symbols and design proposed by CONABIO (2014) within the fifth national communication on biodiversity presented by Mexico to the CBD.

To evaluate the effectiveness of the ICDPs in each NPA required the systematization of the collected information from the interviews and the official sources and academic products about the ICDPs (design, implementation, products, impacts and results). The evaluation comprehends the ICDPs implemented by CNPA from 2009 to 2015 in LT and LP NPAs. The ICDPs were composed by a temporary employment programme (PET, by its Spanish name), by the sustainable development for the conservation programme (PROCODES, by its Spanish name) and by the creole maize conservation programme (PROMAC, by its Spanish name); however, in 2007, the CNPA defined the three programmes as part of the development of the conservation national strategy.

Several authors (Ballart 1993, 1996; Bonnefoy 2005; Martínez 2013) applied the theory of the evaluation of policies and public programmes that focus on three key elements: formulation, implementation and results and proposed effectiveness performance indicators for each one. Therefore, in the design of the ICDPs per NPA studied, we considered the number of years that have each management plan without any review or amendment. At the same time, the indicators were divided into quality indicators, scope indicators and results indicators as follows:

1. Quality ICDP indicators:
   - Number of implemented activities responding to local needs
   - Conservation-oriented actions (Coa)

   (Coa/total actions) *100

2. Scope indicators

   Attended population compared to the target population per ICDP.
   The results of the ICDPs were evaluated using the following indicators:

1. Number of reported species (reported number of species at the NPA decreed vs. current number of species)
2. Quality of water resources
3. Ecosystem coverage (reported coverage at the NPA decreed vs. current coverage) (Table 1.4)

In order to evaluate and assess the opportunities of the management offices of the NPAs for implementing the NP and the AT, the legal and institutional framework and structure were reviewed and contrasted to the requirements that the NP and AT command to build for their implementation. It is important to mention that the NP comprehends 36 articles, but not all of them imply legal and administrative conditions nor constraints that at domestic level parties should develop. We focus our attention on the articles that specify a national capability building for implementing both instruments.

In Mexico, these requirements can be divided into the following categories:

Domestic Legislation

- Article 1: Objective
  - The objective of this Protocol is the fair and equitable sharing of the benefits arising from the utilization of genetic resources, including by appropriate

Table 1.4 ICDP evaluation elements

Evaluation of the ICDP	Evaluation elements	Effectiveness	Circumstances that affect effectiveness	Performance indicators
Design	Problem identification and definition	Local problems	Year when ICDPs were designed	Year of the last harmonization process to the legal amended framework
	Objectives and goals			
	Policies	Application of ICDPs in concordance to local, state, national and international policies		
Implementation	Operative decisions	Monitoring, report and verification	Monitoring frequency and scope	Quality of implementation of ICDPs
	Implemented actions	Quality of the services		Actions respond to population needs
		Scope of the activities		Actions related to conservation
				Effectiveness of scope (attended population vs. target population)
Results	Results measurement	Species status	External issue that impacted biodiversity	Number of species loss
	Conservation and development impacts	Ecosystem improvements		Quality of water resources
		User perception		Mangrove coverage

Source: Galindo-González (2016)

access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding, thereby contributing to the conservation of biological diversity and the sustainable use of its components.

- Article 5: Fair and equitable benefit sharing
  - In accordance with Article 15, paragraphs 3 and 7 of the Convention, benefits arising from the utilization of genetic resources as well as subsequent applications and commercialization shall be shared in a fair and equitable way with the Party providing such resources that is the country of origin of such resources or a Party that has acquired the genetic resources in accordance with the Convention. Such share would be upon mutually agreed terms.
  - Each Party shall take legislative, administrative or policy measures, as appropriate, with the aim of ensuring that benefits arising from the utilization of

genetic resources that are held by indigenous and local communities, in accordance with domestic legislation regarding the established rights of these indigenous and local communities over these genetic resources, are shared in a fair and equitable way with the communities concerned, based on mutually agreed terms.
  - Benefits may include monetary and nonmonetary benefits, including but not limited to those listed in the Annex.

- Article 7: Access to traditional knowledge associated with genetic resources
  - In accordance with domestic law, each Party shall take measures, as appropriate, with the aim of ensuring that traditional knowledge associated with genetic resources that is held by indigenous and local communities is accessed with the prior and informed consent or approval and involvement of these indigenous and local communities and that mutually agreed terms have been established.

- Article 12: Traditional knowledge associated with genetic resources
  - In implementing their obligations under this Protocol, Parties shall in accordance with domestic law take into consideration indigenous and local communities' customary laws, community protocols and procedures, as applicable, with respect to traditional knowledge associated with genetic resources.
  - Parties, with the effective participation of the indigenous and local communities concerned, shall establish mechanisms to inform potential users of traditional knowledge associated with genetic resources about their obligations, including measures as made available through the Access and Benefit-sharing Clearing-House for access to and fair and equitable sharing of benefits arising from the utilization of such knowledge.
  - Parties shall endeavour to support, as appropriate, the development by indigenous and local communities, including women within these communities, of:

    Community protocols in relation to access to traditional knowledge associated with genetic resources and the fair and equitable sharing of benefits arising out of the utilization of such knowledge

    Minimum requirements for mutually agreed terms to secure the fair and equitable sharing of benefits arising from the utilization of traditional knowledge associated with genetic resources

    Model contractual clauses for benefit sharing arising from the utilization of traditional knowledge associated with genetic resources

  - Parties, in their implementation of this Protocol, shall, as far as possible, not restrict the customary use and exchange of genetic resources and associated traditional knowledge within and among indigenous and local communities in accordance with the objectives of the Convention.

- Article 15: Compliance with domestic legislation or regulatory requirements on access and benefit sharing
  - Each Party shall take appropriate, effective and proportionate legislative, administrative or policy measures to provide that genetic resources utilized within its jurisdiction have been accessed in accordance with prior informed consent and that mutually agreed terms have been established, as required by the domestic access and benefit-sharing legislation or regulatory requirements of the other Party.
  - Parties shall take appropriate, effective and proportionate measures to address situations of non-compliance with measures adopted in accordance with paragraph 1 above.
  - Parties shall, as far as possible and as appropriate, cooperate in cases of alleged violation of domestic access and benefit-sharing legislation or regulatory requirements referred to in paragraph 1 above.
- Article 16: Compliance with domestic legislation or regulatory requirements on access and benefit sharing for traditional knowledge associated with genetic resources
  - Each Party shall take appropriate, effective and proportionate legislative, administrative or policy measures, as appropriate, to provide that traditional knowledge associated with genetic resources utilized within their jurisdiction has been accessed in accordance with prior informed consent or approval and involvement of indigenous and local communities and that mutually agreed terms have been established, as required by domestic access and benefit-sharing legislation or regulatory requirements of the other Party where such indigenous and local communities are located.
  - Each Party shall take appropriate, effective and proportionate measures to address situations of non-compliance with measures adopted in accordance with paragraph 1 above.
  - Parties shall, as far as possible and as appropriate, cooperate in cases of alleged violation of domestic access and benefit-sharing legislation or regulatory requirements referred to in paragraph 1 above.
- Article 17: Monitoring the utilization of genetic resources
  - To support compliance, each Party shall take measures, as appropriate, to monitor and to enhance transparency about the utilization of genetic resources. Such measures shall include:

    The designation of one or more checkpoints, as follows:

    - Designated checkpoints would collect or receive, as appropriate, relevant information related to prior informed consent, to the source of the genetic resource, to the establishment of mutually agreed terms and/or to the utilization of genetic resources, as appropriate.

- Each Party shall, as appropriate and depending on the particular characteristics of a designated checkpoint, require users of genetic resources to provide the information specified in the above paragraph at a designated checkpoint. Each Party shall take appropriate, effective and proportionate measures to address situations of non-compliance.
- Such information, including from internationally recognized certificates of compliance where they are available, will, without prejudice to the protection of confidential information, be provided to relevant national authorities, to the Party providing prior informed consent and to the Access and Benefit-sharing Clearing-House, as appropriate.
- Checkpoints must be effective and should have functions relevant to implementation of this subparagraph (a). They should be relevant to the utilization of genetic resources, or to the collection of relevant information at, inter alia, any stage of research, development, innovation, pre-commercialization or commercialization.

Encouraging users and providers of genetic resources to include provisions in mutually agreed terms to share information on the implementation of such terms, including through reporting requirements

Encouraging the use of cost-effective communication tools and systems

– A permit or its equivalent issued in accordance with Article 6, paragraph 3 (e) and made available to the Access and Benefit-sharing Clearing-House, shall constitute an internationally recognized certificate of compliance.
– An internationally recognized certificate of compliance shall serve as evidence that the genetic resource which it covers has been accessed in accordance with prior informed consent and that mutually agreed terms have been established, as required by the domestic access and benefit-sharing legislation or regulatory requirements of the Party providing prior informed consent.
– The internationally recognized certificate of compliance shall contain the following minimum information when it is not confidential:

Issuing authority
Date of issuance
The provider
Unique identifier of the certificate
The person or entity to whom prior informed consent was granted
Subject matter or genetic resources covered by the certificate
Confirmation that mutually agreed terms were established
Confirmation that prior informed consent was obtained
Commercial and/or non-commercial use

- Article 18: Compliance with mutually agreed terms

– In the implementation of Article 6, paragraph 3 (g) (i) and Article 7, each Party shall encourage providers and users of genetic resources and/or traditional knowledge associated with genetic resources to include provisions in mutually agreed terms to cover, where appropriate, dispute resolution including:

The jurisdiction to which they will subject any dispute resolution processes
The applicable law
Options for alternative dispute resolution, such as mediation or arbitration

- Each Party shall ensure that an opportunity to seek recourse is available under their legal systems, consistent with applicable jurisdictional requirements, in cases of disputes arising from mutually agreed terms.
- Each Party shall take effective measures, as appropriate, regarding:

Access to justice
The utilization of mechanisms regarding mutual recognition and enforcement of foreign judgements and arbitral awards

- The effectiveness of this article shall be reviewed by the Conference of the Parties serving as the meeting of the Parties to this Protocol in accordance with Article 31 of this Protocol.

Public Administration

- Article 8: Special considerations
  - In the development and implementation of its access and benefit-sharing legislation or regulatory requirements, each Party shall:
  - Create conditions to promote and encourage research which contributes to the conservation and sustainable use of biological diversity, particularly in developing countries, including through simplified measures on access for non-commercial research purposes, taking into account the need to address a change of intent for such research.
  - Pay due regard to cases of present or imminent emergencies that threaten or damage human, animal or plant health, as determined nationally or internationally. Parties may take into consideration the need for expeditious access to genetic resources and expeditious fair and equitable sharing of benefits arising out of the use of such genetic resources, including access to affordable treatments by those in need, especially in developing countries.
  - Consider the importance of genetic resources for food and agriculture and their special role for food security.
- Article 9: Contribution to conservation and sustainable use
  - The Parties shall encourage users and providers to direct benefits arising from the utilization of genetic resources towards the conservation of biological diversity and the sustainable use of its components.

- Article 13: National focal points and competent national authorities
  - Each Party shall designate a national focal point on access and benefit sharing. The national focal point shall make information available as follows:
  - For applicants seeking access to genetic resources, information on procedures for obtaining prior informed consent and establishing mutually agreed terms, including benefit sharing
  - For applicants seeking access to traditional knowledge associated with genetic resources, where possible, information on procedures for obtaining prior informed consent or approval and involvement, as appropriate, of indigenous and local communities and establishing mutually agreed terms including benefit sharing
  - Information on competent national authorities, relevant indigenous and local communities and relevant stakeholders:
- The national focal point shall be responsible for liaison with the Secretariat.
- Each Party shall designate one or more competent national authorities on access and benefit sharing. Competent national authorities shall, in accordance with applicable national legislative, administrative or policy measures, be responsible for granting access or, as applicable, issuing written evidence that access requirements have been met and be responsible for advising on applicable procedures and requirements for obtaining prior informed consent and entering into mutually agreed terms.
- A Party may designate a single entity to fulfil the functions of both focal point and competent national authority.
- Each Party shall, no later than the date of entry into force of this Protocol for it, notify the Secretariat of the contact information of its national focal point and its competent national authority or authorities. Where a Party designates more than one competent national authority, it shall convey to the Secretariat, with its notification thereof, relevant information on the respective responsibilities of those authorities. Where applicable, such information shall, at a minimum, specify which competent authority is responsible for the genetic resources sought. Each Party shall forthwith notify the Secretariat of any changes in the designation of its national focal point or in the contact information or responsibilities of its competent national authority or authorities.
- The Secretariat shall make information received pursuant to paragraph 4 above available through the Access and Benefit-sharing Clearing-House.

Capacity Building for the Management Plan of Each NPA

- Article 21: Awareness-Raising
  - Each Party shall take measures to raise awareness of the importance of genetic resources and traditional knowledge associated with genetic resources, and related access and benefit-sharing issues. Such measures may include, inter alia:

    Promotion of this Protocol, including its objective

    Organization of meetings of indigenous and local communities and relevant stakeholders

Establishment and maintenance of a help desk for indigenous and local communities and relevant stakeholders
Information dissemination through a national clearing-house
Promotion of voluntary codes of conduct, guidelines and best practices and/or standards in consultation with indigenous and local communities and relevant stakeholders
Promotion of, as appropriate, domestic, regional and international exchanges of experience
Education and training of users and providers of genetic resources and traditional knowledge associated with genetic resources about their access and benefit-sharing obligations
Involvement of indigenous and local communities and relevant stakeholders in the implementation of this Protocol
Awareness raising of community protocols and procedures of indigenous and local communities

- Article 22: Capacity

  - The Parties shall cooperate in the capacity building, capacity development and strengthening of human resources and institutional capacities to effectively implement this Protocol in developing country Parties, in particular the least developed countries and small island developing States among them, and Parties with economies in transition, including through existing global, regional, subregional and national institutions and organizations. In this context, Parties should facilitate the involvement of indigenous and local communities and relevant stakeholders, including non-governmental organizations and the private sector.
  - The need of developing country Parties, in particular the least developed countries and small island developing States among them, and Parties with economies in transition for financial resources in accordance with the relevant provisions of the Convention shall be taken fully into account for capacity building and development to implement this Protocol.
  - As a basis for appropriate measures in relation to the implementation of this Protocol, developing country Parties, in particular the least developed countries and small island developing States among them, and Parties with economies in transition should identify their national capacity needs and priorities through national capacity self-assessments. In doing so, such Parties should support the capacity needs and priorities of indigenous and local communities and relevant stakeholders, as identified by them, emphasizing the capacity needs and priorities of women.
  - In support of the implementation of this Protocol, capacity building and development may address, inter alia, the following key areas:

Capacity to implement, and to comply with the obligations of, this Protocol
Capacity to negotiate mutually agreed terms

Capacity to develop, implement and enforce domestic legislative, administrative or policy measures on access and benefit sharing
Capacity of countries to develop their endogenous research capabilities to add value to their own genetic resources

– Measures in accordance with paragraphs 1–4 above may include, inter alia:

Legal and institutional development
Promotion of equity and fairness in negotiations, such as training to negotiate mutually agreed terms
The monitoring and enforcement of compliance
Employment of best available communication tools and Internet-based systems for access and benefit-sharing activities
Development and use of valuation methods
Bioprospecting, associated research and taxonomic studies
Technology transfer and infrastructure and technical capacity to make such technology transfer sustainable
Enhancement of the contribution of access and benefit-sharing activities to the conservation of biological diversity and the sustainable use of its components
Special measures to increase the capacity of relevant stakeholders in relation to access and benefit sharing
Special measures to increase the capacity of indigenous and local communities with emphasis on enhancing the capacity of women within those communities in relation to access to genetic resources and/or traditional knowledge associated with genetic resources

– Information on capacity building and development initiatives at national, regional and international levels, undertaken in accordance with paragraphs 1–5 above, should be provided to the Access and Benefit-sharing Clearing-House with a view to promoting synergy and coordination on capacity building and development for access and benefit sharing.

• Article 23: Technology transfer, collaboration and cooperation

  – In accordance with Articles 15, 16, 18 and 19 of the Convention, the Parties shall collaborate and cooperate in technical and scientific research and development programmes, including biotechnological research activities, as a means to achieve the objective of this Protocol. The Parties undertake to promote and encourage access to technology by, and transfer of technology to, developing country Parties, in particular the least developed countries and small island developing States among them, and Parties with economies in transition, in order to enable the development and strengthening of a sound and viable technological and scientific base for the attainment of the objectives of the Convention and this Protocol. Where possible and appropriate, such collaborative activities shall take place in and with a Party or the Parties providing genetic resources that is the country or are the countries of origin of such resources or a Party or Parties that have acquired the genetic resources in accordance with the Convention.

To assess the compliance of the AT, the legal and institutional framework were analysed against the strategic objectives of the Strategic Programme 2011–2020. For determining the achievement prospects for the AT in the NPAs, we performed an analysis of strengths, weaknesses, opportunities and threats (SWOT), which was sustained by the previous analysis and the results obtained of the previous specific objectives of this research.

1.3 Results

Management effectiveness of each one of the NPAs required an exhaustive review of numerous elements, documents and field trips for developing the final analysis that is synthesized in Table 1.5 according to Hockings et al. (2006) elements. Each element compiled several components that characterized the most important management issue that was similar or shared. The qualitative ranking was proposed after placing an artificial scale from zero to four and adding points if the NPA had the component and if it contributed positively or negatively for assessing the managing performance. Negative effects had zero to one point; positive effects had four points; decreasing effects had two points; and increasing effects had three points.

In a fair balance of the elements and components, it is important to notice that both NPAs ranked very low, and this rank is due to a number of current issues that have contributed to a failed management effectiveness. Reviewing the context for both NPAs is to define the social and environmental viability for biodiversity conservation and sustainable development policies and plan implementation. The considered elements to assess the context of each NPA were the ecosystems status, levels of threats and the current health state of biodiversity. At the same time, the human settlements inside the NPA area and within the influence zone were sampled to know their productive activities and style of living, the indigenous uses and traditional costume prevalence that may be reflected in the NPA management, their perception and level of NPA acceptance as an asset, as well as the evaluation of the authority presence.

1.3.1 Biodiversity and Ecosystems Status

The status quo of the biodiversity and ecosystems were the key indicators for assessing the effectiveness of each NPA. Wetland and mangrove coverage in coastal areas give the health signs that we would have been looking for evaluating the stress versus the performance of the NPA to deter such impacts. Both wetlands and mangroves conform the critical habitats for a number of marine and terrestrial species, as well as the producers of the first link in the trophic chain. Their coverage together with their distribution, structure and ecosystemic composition are relevant elements to consider in the assessment. Due to a number of economic and profitable

Table 1.5 Ranking the effectiveness of the management performance per NPA Laguna de Términos (LT) and Los Petenes (LP) biosphere reserve

Management elements (Hockings et al. 2006)	Components	LT	LP
Context	Key ecosystemic elements	←	↑
	Cultural indigenous background	↓	↑
	Distinctive socio-economic features	←	→
Planning	Management plan	↓	↓
	Annual operative plans	←	←
	Location of the management plan office	↑	↓
Inputs	Institutional capacity (trained staff, equipment, budget)	→	→
	Scientific research	↑	→
	Social capital	↓	→
Processes	Governance	←	→
	Communication capacities, networking	→	→
	Environmental education plans	→	↓
Products	NGOs present and collaborating	←	→
	Publications, joint projects	↑	→
	Workshops, committees	↓	↑
Results	Biodiversity and ecosystems healthier and well conserved	↓	↓
	Positive changes in social perception and attitudes towards the NPA	→	→
	Position of the CNPA within the federal government and at local level	→	→
Keys	Total points	38	46
←	Diminishing the positive effect (2 points)		
↑	Positive effect (4 points)		
→	Increasing the positive effects (3 points)		
↓	Negative effect (0–1 point)		

activities, these ecosystems are under constant pressure to be destroyed or diminished, leaving small patches that cannot fulfil ecosystem functions and eventually are vanished.

LT accounts five seagrass species *Thalassia testudinum, Halodule wrightii, Syringodium filiforme, Halophila engelmannii and Ruppia marítima*, with *T. testudinum* as the dominant species (Espionosa-Ávalos 1996). LT embraces 239,966 ha of wetlands that are composed by 123,326 ha of mangroves and 116,641 ha of different types of wetlands (Bezaury-Creel 2009, 2010). The species distribution in LT is due to the hydrological patterns, the residence water rate, fresh and marine water fluxes and salinity rates during the different seasons along the year (Yañez-Arancibia and Day 2005). Considering all these factors, it is possible to identify two main lagoon regions: east and west (Botello 1977); the latter is characterized by the riverine influence; meanwhile the east part is more influenced by the dominant wind patterns and the marine currents and diurnal and semidiurnal tides with an average of 0.5 m (Ortega 1995). After more than 20 years, these biodiversity data are obsolete, and it is very important to have extended and deep fieldwork to evaluate the current biodiversity and ecosystems coverage status.

Primary productivity of LT sustained the trophic chain of 40% of the demersal fisheries and more of the 50% of the shrimp captures in the Gulf of Mexico (Lara-Domínguez and Yáñez-Arancibia 1999). The health state of LT biodiversity is given by maintaining – or increasing – the number of species. The management plan published in 1997 accounted 374 flora species and 1468 fauna species both marine and land, 89 of those species under any some category.

On the other hand, the LP accounts 12 nautical miles within its protected area, which presents 763 km^2 of seabed grasses composed by *Thalassia testudinum, Syringodium filiforme* and *Halodule wrightii* (Gallegos et al. 2012). LP also embraced 87,890 ha of wetlands (according to the management plan in 2006), which was previously reported as mangroves by Mas et al. (2000), who made a classification as follows: 72,818 ha of mangroves, 11,603 ha of blanquizales, 19,878 ha of marshes and 17,351 ha of Petenes. According to Gray and Palacios (1996), the salinity gradients combined by the freshwater inputs modulated the distribution of the flora species as a petén or as a mixed mangrove. More than 10 years have passed without any updating to the biodiversity data, satellite images have shown differences in vegetation coverage but still require extensive fieldwork for giving more accurate results.

LP is also characterized by high primary productivity (Muñoz-Rojas et al. 2013), which allows the development of fly catch of shad and bass (RBLP_NU06 in Galindo-González 2016). The management plan published in 2006 accounted 1151 of flora species and 434 of fauna species both marine and land. And from those species, 43 bird species and 16 mammal species are under some risk category.

1.3.2 Human Settlements

As presented above, LT contains with most of the settlements of both municipalities, Carmen and Palizada, and includes two small towns in Champoton and four in Tabasco State in the municipalities of Jonuta and Centla. The total population of Carmen and Palizada add up to 229,446 people in which 40% is economically active. People in LT are involved in high-pressure activities to the NPA, such as (1) oil and gas exploration and extraction, (2) illegal fisheries within the coastal lagoon and (3) mangrove and wetland filling, logging, charcoal-making and intentional fires.

In LT only 1.3% speaks an indigenous language (INEGI 2010). The interstate road 180 crosses the LT parallel to the coastline, making it very vulnerable to sea level rise. And at least 71% of the total population have public services; but 75% of the settlements are classified with economic marginalization (INEGI 2010). Despite the fact that LT has suffered a decrement of their traditional cultures, many people still practise hunt and recollection, especially in the Chontal zone along the riverine-lagoon system of LT (Vadillo 2008). However, modern techniques have imposed a more intensive capture producing higher impacts to the biodiversity of the NPA, particularly over risk species such as the manatee.

On the other hand, LP with four municipalities involved accounts a total population of 349,937 people, which 42% is economically active. Many economic activities within the LP are derived from traditional uses such as maize production, small domestic animals in their backyards, handcraft making and migrating to neighbour towns for temporal jobs. However, with octopus and marine cucumber profitable fisheries, many of those people abandon their traditional fields and shift to these activities imposing a high impact to the NPA without any control (INAPESCA 2012).

Through this four municipalities are settled more of the half of Maya speakers of Campeche State (INEGI 2010). Located in a land strip parallel to the coastal zone, which is called Camino Real with cultural similarities, this quality according to Leenhardt et al. (2015) makes easier the NPA management. Most of the settlements in LP share the same Mayan background that came through the history of the henequen haciendas (1860–1960) that transformed the landscape. After their collapsed, the Mayan descendants continued to apply traditional knowledge to their agriculture, apiculture, meliponiculture and hunting and identified themselves with the conservation purpose of the NPA. Although public services cover 93% of these settlements, 83.33% of them are catalogued as high marginalized (Rosas-Vargas 2007; INEGI 2010). The main communication is through the interstate road 180, which is parallel to the coastal zone and passes through LP's influence zone.

1.3.3 Management Plan of Each NPA

For the purpose of this research, the management plans were evaluated to demonstrate the consistency of each one of the plan's contents according to the legal framework; and it was also evaluated the effectiveness of their implementation using the consistency of the annual programme of operation with the management plan per NPA.

Each management plan should contain at least the components established by Articles 60 and 66 of the General Environmental and Protection Law. And the implementation of each one of these components was assessed considering their (a) objectives, (b) internal organization and structure, (c) advisory councils, (d) social links, (e) scope and zoning, (f) biological inventories, (g) land tenure, (h) regulations, (i) administrative regulations, (j) inter-sectoral link of the management plan and (k) review and update of the management plan each 5 years.

After reviewing each one of these components, it was evident to point out the following issues:

1. The advances in management approaches have changed internationally and domestically; therefore, these plans and objectives require extensive review and even redesign.
2. Management Plans with more than 20 and 10 years old without any review and update gives enough reasons and opportunities for performing in-depth insights and possibly redirecting some objectives and goals, as well as the scope, zoning and, with urgency, updating the biological inventories and ecosystems coverage.
3. Despite the fact that both NPAs have advisory committees, these are useless if they do not operate.
4. It is evident that social perception towards the benefits coming from the NPAs is the result of external factors rather than the management office intervention nor the implementation of the management plan.
5. Both NPAs lack means to charge for any of the services nor activities performed by users inside the area. This has to change if each NPA wants more budgets to work with.
6. There is an evident lack or very poor linkage with other sectors that operate outside the NPA. Each sectorial activity has impacts that trespass the areas' frontiers that have not been approached nor addressed, less solved.

1.3.4 Effectiveness Assessment Through the Implementation of the Annual Operation Plan

For this assessment, the annual operating plans (AOP) of each NPA were reviewed from 2010 to 2015, since they did not keep older AOPs. LT management plan contains only 184 actions in order to fulfil its implementation. However, AOPs showed that only 29 were attended, whereas another 62 were done that were necessary but not even considered within the management plan, including climate change actions. The planned activities to protect and conserve biodiversity were (a) fire management, (b) community rangers, (c) subsidy plans for maize, (d) design of especial conservation programs for endangered species, such as marine turtles, and (e) environmental education.

All the LT AOPs analysed accounted a total of 246 activities, which were supposed to be programmed year after year. To define the necessary effort required to implement such action, CNPA uses evaluation elements such as a measure unit (MU), an annual goal (AG) and a verifying mean (VM). However, while trying to evaluate these AOPs, the results were impossible to analyse:

- Twenty-eight activities change the MU, making impossible to follow up for the following years.
- Nineteen activities reduced their AG, while 23 increased it.
- Eighteen activities made a different use of the evaluation elements and programmed everything in different periods of time.
- Sixteen activities showed a minimum effort according to the size of the NPA.
- More than five activities were programmed duplicating them within the same AOP.
- More than twice, there were changes of the MU for the VM and vice versa.

The management plan of LP establishes only 363 actions to achieve the different goals to address the objectives. Nevertheless, according to its AOP, during these 11 years, only 95 actions were implemented. The most common were community rangers and fire management; however, it is outside its jurisdiction to promote protection actions since those are the area of the Environmental Protection Agency (PROFEPA). Another action outside the management plan was the building of an office in Sodzil which was programmed in the AOPs 2011 and 2012, as well as the implementation of three units for environmental management that were planned for AOPs 2011, 2012 and 2013 and that only one was reactivated (in Pucnaché) and the design and implementation of the "public use programme" in AOPs 2013 and 2014.

In LP, from the 199 planned activities in the period 2010–2015, there were the following issues:

- For 16 activities, the VM and/or the MU were different for the various years.
- For 33 activities had VM and/or MU no relation whatsoever with the action.
- Twenty activities reduced the AG from the previous year.
- For 41 activities, the AG programmed represented an insufficient effort considering the management plan and the nature of the activity.
- The same activity was repeated within the same AOP four times.

External and previous evaluations have pointed out some of these issues, especially that CNPA does not fulfil the conservation objectives and make an incongruous use of the indicators (IGICHAC 2009). Another problem is that the AOP is a useless tool that would not serve the purposes nor help to make an effective conservation management.

A determinant factor for management, administrative purposes and greenhouse gas (GHG) emissions is the location of the directive office of each NPA (Dumoulin et al. 2014). The main objective is to serve as focal points for communication with the CNPA and grant different users and public attention, planning activities and their implementation. These offices are strategically located to favour the development of necessary ventures for management goals, seeking to cover the proper scope to deliver effective management. To make an assessment of the management offices, it is necessary to take into consideration all these factors plus the institutional capacity in terms of human capital, budget, equipment, etc. Therefore, location of the management office is very important to achieve the NPA's goals.

LT management office is located in Ciudad del Carmen, the second largest city in the state of Campeche. It is also the oil capital of the Gulf of Mexico; so, location in this case facilitated the interaction with major users and sectors allowing to participate and present a direct position towards the impacts received upon its ecosystems and biodiversity. This location proved very useful to link activities with Atasta, Sabancuy and Champotón but made it harder to establish a linkage with Palizada. Despite this fact, the management office had a good location.

LP management office is located in Campeche City, the capital of the state of the same name, and the extreme south of the protected area. Nevertheless, the largest percentage of the NPA activities takes place kilometres away from it (Fig. 1.8), making it really difficult to translate and travel all along the NPA, both by land or sea.

The number of actions implemented by the CNPA in the municipality of Campeche is very few, giving the fact that it is the less poor but more culturally and ethnically diverse of all the municipalities covered by the NPA. The rest of the settlements require bilingual skills that affect the relationships and communication among different actors of LP.

In field the results of this lack of communication were observed in the extremely different conception of the concept and objective of the CNPA and the NPA by users and non-users, which also has affected community participation in the ICDP implementation.

A major issue in the institutional capacity of the NPA is their budget and is a powerful link between this and effectiveness. Each management office allocates their budgets according to their needs and activities planned in the AOP. Table 1.6 shows the comparison of these budgets for both NPAs that change year, after year.

Analysing the budget for LP during the 2009–2015 period, it is shown that it was larger than the LT's. We may consider that there was around \$274.38/year/km^2 for LP and \$80.50/year/km^2 for LT. Both budgets are within the average rank that the CNPA grants per NPA in Mexico (Rivera 2011). However, LT got 1.61 times more budget from subsidiary programmes than LP. It was found that usually LT has access to international fund grants, which gives more autonomy to this NPA than LP which depends entirely to the national financing. Also, between both NPAs there are differences between the efficiency in the resource management (Tables 1.7 and 1.8).

An important finding was that by the month of August, only 9.18% of the PROMAC and PROCODES budget were spent, which force the management office to spend the rest of the fiscal yearly budget as soon as possible, which could affect both the process and the efficacy of the results of the implemented budget. Meanwhile, LT turns to have a more efficient use of the budget according to Table 1.8.

LT seems to have an efficient use of the budget, and the results of the subsidized programmes are good. And by August the management office has already spent more than 50% of its budget.

Institutional capacity in coastal NPAs is based importantly by the owned equipment for traveling all along the NPA. An analysis was made in Table 1.9 to register

Table 1.6 Approved budgets for the period of 2010–2015 of LT and LP NPAs

Authorized budget (in pesos)								
		Subsidy programmes						
LP	Fiscal	PET	PROCER	PROMOBI	PROVICOM	PROMAC	PROMANP	PROCODES
2009	$425,609.32	$0.00	$0.00	$0.00	$0.00	$1,200,000.00	$0.00	$1,510,391.60
2010	$755,481.54	$549,202.84	$0.00	$0.00	$0.00	$712,500.00	$0.00	$1,306,869.94
2011	$422,375.11	$764,714.00	$0.00	$0.00	$293,286.00	$1,130,699.00	$0.00	$1,351,410.00
2012	$1,052,459.02	**$2,743,741.00**	$0.00	$0.00	$386,150.00	**$1,186,000.00**	$0.00	$1,245,800.00
2013	$804,742.33	$695,815.00	$0.00	$0.00	$292,497.00	$931,992.00	$0.00	$1,659,828.00
2014	$855,182.97	$486,384.00	$0.00	$0.00	$165,000.00	$805,392.00	$0.00	$2,024,400.00
2015	$1,116,943.93	$245,370.31	$0.00	$325,000.00	$0.00	$999,587.00	$189,000.00	$2,063,800.00
Subtotal	$5,432,794.22	$5,485,227.15	$0.00	$325,000.00	$1,136,933.00	$6,966,170.00	$189,000.00	$11,162,499.54
LT		**Total=**					**$25,264,829.69**	
2009	$490,298.00	$583,292.00	$0.00	$0.00	$0.00	$0.00	$0.00	$3,240,000.00
2010	$370,000.00	$577,984.00	$0.00	$0.00	$0.00	$0.00	$0.00	$2,716,600.00
2011	$553,497.00	$1,678,648.00	$0.00	$314,179.00	$374,792.00	$0.00	$0.00	$3,000,000.00
2012	$608,847.00	$1,453,350.00	$0.00	$356,429.00	$413,838.00	$0.00	$733,588.00	$2,899,291.00
2013	$614,935.00	$2,479,027.00	$475,951.00	$733,588.00	$543,684.00	$0.00	$0.00	$3,519,339.00
2014	$678,429.00	$2,636,925.00	$1,038,852.00	$731,682.00	$683,732.00	$0.00	$0.00	$3,020,907.00
2015	$662,975.00	$1,316,908.00	$1,861,982.00	$0.00	$504,939.00	$0.00	$0.00	$2,732,322.00
Subtotal	**$3,978,981.00**	**$10,726,134.00**	**$3,376,785.00**	**$2,135,878.00**	**$2,520,985.00**	**$0.00**	**$733,588.00**	**$21,128,459.00**
		Total=					**$40,621,829.00**	

Source: CNPA (2016)

PET temporal employment programme, *PROMOBI* biological monitoring programme in NPAs, *PROVICOM* community surveillance programme, *PROMAC* creole maize conservation programme, *PROMANP* management of NPA programme, *PROCODES* conservation for sustainable development programme

Table 1.7 Budget efficiency of LP

LP	PET			PROCODES			PROMAC		
Year	Spent	Authorized	Spent/authorized	Spent	Authorized	Spent/authorized	Spent	Authorized	Spent/authorized
2010	$549,202.84	$549,202.84	100%	$1,254,595.14	$1,306,869.94	96%	$1,389,204.00	$712,500.00	195%
2011	$764,714.00	$764,714.00	100%	$1,299,520.00	$1,351,410.00	96%	$1,043,861.40	$1,130,699.00	92%
2012	$884,000.00	$2,743,741.00	32%	$1,204,539.10	$1,245,800.00	97%	$1,154,215.20	$1,186,000.00	97%
2013	$529,621.00	$695,815.00	76%	$1,603,026.00	$1,659,828.00	97%	$910,556.18	$931,992.00	98%
2014	$478,134.00	$486,384.00	98%	$1,957,373.00	$2,024,400.00	97%	$791,000.00	$805,392.00	98%
2015	$136,400.00	$245,370.31	56%	$189,500.00	$2,063,800.00	9%	ND	$999,587.00	–

Source: IFAI data

Table 1.8 Budget efficient of LT

LT	PET			PROCODES		
Year	Spent	Authorized	Spent/authorized	Spent	Authorized	Spent/authorized
2009	$583,292.39	$583,292.39	100%	$3,110,400.00	$3,240,000.00	96%
2010	$577,984.00	$577,984.00	100%	$2,607,936.00	$2,716,600.00	96%
2011	$1,678,647.59	$1,678,647.59	100%	$2,884,800.00	$3,000,000.00	96%
2012	$1,453,340.46	$1,453,340.46	100%	$2,802,912.00	$2,899,291.00	97%
2013	$2,401,190.57	$2,479,027.00	97%	$3,408,090.50	$3,519,339.00	97%
2014	$2,603,370.37	$2,636,295.00	99%	$2,930,067.70	$3,020,907.00	97%
2015	$804,596.00	$1,316,908.00	61%	$2,252,875.00	$2,732,322.00	82%

Source: IFAI

Table 1.9 Number and type of vehicles per NPA

Type of vehicles (1996–2015)	LT		LP	
	Number of vehicles	Coverage*/ vehicle	Number of vehicles	Coverage*/ vehicle
Van	7	50,226.0	5	20,187.5
Small car	0	0	1	100,937.4
Motorcycle	2	175,791.0	1	100,937.4
Field motorcycle	6	58,597.0	1	100,937.4
Boats with motor	5	70,686.8	1	181,919.70
Kayak	0	0	2	90,959.9
Aquatic motorcycle	0	0	1	181,919.70
*Land coverage (Ha)	351,582.00		100,937.40	
*Water coverage (Ha)	353,434.00		181,919.70	

Source: IFAI

the type and number of vehicles since 1996–2015 that belong to each NPA and the kilometres they can cover.

From these results, it is evident that LT has got a largest capacity for land and water coverage. In any case, neither NPA has the sufficient number of vehicles for their personnel. Furthermore, each management office for each NPA has got only one rented building, affecting the presence of the NPA all along each of the NPA. However, the relationship of the NPA's area to their staff is 1:1.85, which means that each one is entitled to take care of nearly 59,000 ha in LT 76.5 thousand hectares in LP per person. Just to make a comparison, at international level the rate is 27 staff members each 100,000 ha (CONANP 2014); therefore the LP would require 76 more people and LT 190 more people.

At this point we wanted to know how the NPA management office made decisions. And how does the NPA office make any effective management? So, we considered both the NPAs governance which are based on a co-management model (Borrini-Feyerabend et al. 2014), considering that there are a mix of three different types of land tenure. Nevertheless, it is the federal component the one with the leading position and the decision-making process that is supposed to lead towards sustainable development and biodiversity conservation.

Local authorities at municipal levels do not take active participation and leave all responsibilities to the federal order. There is no presence of organized civil society in LT. Nevertheless, there is no presence of society in the decision-making process in both NPAs. Most of the so-called social groups are confirmed by the kin organization system, due to the lack of trust in "the other", which has as consequence poor formality in decision-making results in weak agreements and conflicts.

On the other hand, field interviews sustained that subsidy programmes have originated negative impacts within the communities, giving the impression to the CNPA managers that only if there is money, they would get involved and work for conservation purposes. This shows out that the NPA managers are not considering the huge job insecurity in both NPAs as in the entire country. Assessment shows that the

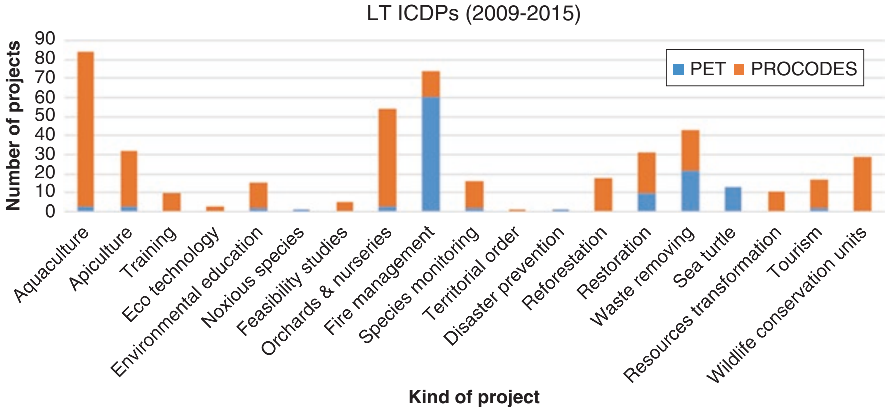

Fig. 1.2 Number of projects per ICDPs in Laguna de Términos. (Source: Information requested from IFAI)

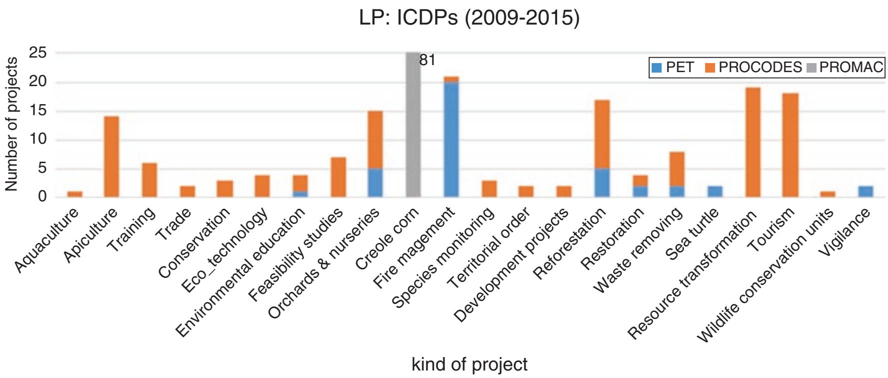

Fig. 1.3 Number of projects per ICDPs in Los Petenes. (Source: Information requested from IFAI)

management office's communication failures results in desinformation and missunderstandings with local communities about programs mission and goals.

The above voids mentioned, related to the planning and communication, are reflected on the number and kind of projects allocated in the NPAs. During the 2009–2015 period, there were implemented 458 projects in LT, 336 were from PROCODES and the rest from PET (Fig. 1.2). During the same period, there were implemented 296 projects in LP (Fig. 1.3), 41 of them were PET, 153 PROCODES and 102 PROMAC, which gives an average of 49.3 projects per year.

However, any project was monitored which resulted in failed achievement of the proposed goals. The reasons for this lack on monitoring are due to several factors as the lack in number of personnel in both NPAs, continuous decreasing of budget for monitoring and others, which according to the NPA managers just in the implementation period socio-economic benefits can be observed, as Gurney et al. (2014) report.

It is interesting to notice that in LT there were not implemented any programme nor action to address the hydrology nor water resources, except 24 isolated activities to pick up trash. Also, there were no fishery programmes nor action for either NPA despite both having fishery activities. Even though looking at the aquaculture projects, there is a huge difference between the number of projects implemented in LT and LP, which could be explained by the cultural relationship of people in LT with the freshwater sources in the region, however it's indispensable that the LP management office take more attention to this kind of projects due to the high incidence and overexploitation of marine resources as octopus and sea cucumber.

Figures 1.2 and 1.3 may give the impression of at the NPA management offices, where in LT the major kind of projects implemented were the aquaculture and fire management, this last one supported importantly by the PET in which its biggest weakness is it is shortly temporary, which implies little actions and not precisely an integrated fire management. This is the same for LP, adding to this the temporal lag that occurs between the time that needs fire management actions due to the climatology conditions and the money allocation time, according to findings in the fieldwork.

In regard to PROMAC, only LP, from both, implements actions from this programme. In spite of the importance of conserving creole maize genetics and the entire socio-environmental relations linked to it, the results of this project have little impacts due to the null relationship between conservation policies and economics. The same occurs with the resource transformation projects which refer to the artisan activities, where artisans are benefited through material capital, which consequently makes possible more productivity but not any wealth improvement nor their position on market relations.

It's important to highlight that in both NPAs the huge majority of activities are related to the epicontinental socio-environmental interactions, with a huge void in the coastal and marine interactions. This adds to the lack of inter-sectoral management, mentioned above, a void of integral management vision, which is needed for the coastal ecosystem management (Cicin-Sain and Belfiore 2006).

One of the most important elements for Nagoya Protocol and Aichi Targets is the benefit sharing. This can be measured somehow considering the people that have been benefited from each subsidy programme.

Figure 1.4 shows the interaction between each subsidy programme and the number of people that has been benefited from them. It was found that PROMAC has benefited more people than any other ICDP; however most of the actions imply a direct relation to the maize producer without accounting the internal and communitarian interactions, and without considering the entire value chain, which affects directly to the programme results' effectiveness. It was observed that there is no interaction between the Agriculture Ministry and the Mayor City Office from each municipality; both of these promote agriculture programs based on hybrid seeds and agrochemical supplies, which represent a completely contrary aim in regard to

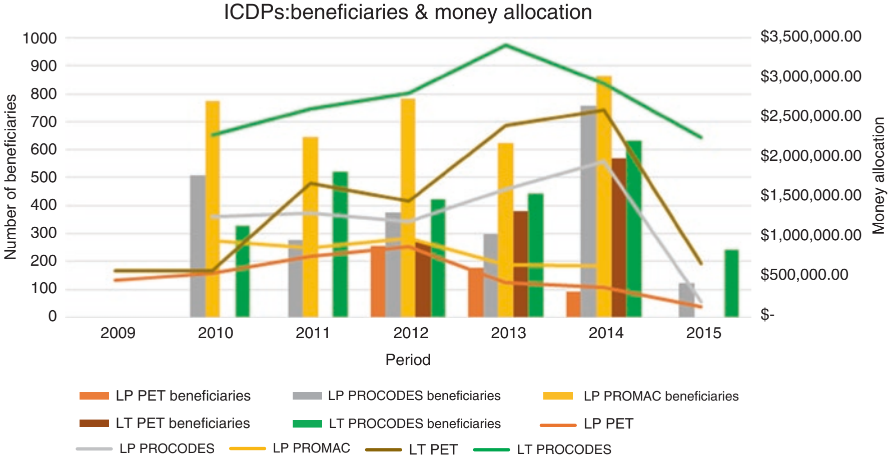

Fig. 1.4 Invested budget and the number of people benefited per subsidy programme. (Source: Information requested from IFAI)

PROMAC. Also, the relation between the money allocation and the number of beneficiaries is disproportionated compared to the PROCODES projects in both NPAs.

As is observed at the last figure, there were no data reported for the number of beneficiaries from the PET projects. It was until 2010 that the federation mandated to do so. This implies that NPA accounting methods are still on the way to its consolidation, which is still observed on the differences of the formats and kind of information for reporting the ICDP development between the different States and its offices.

Another element is the relationship between the implemented activities and addressing the local needs, considering the socioeconomic conditions and current development potentials (Silva 2003). To calculate an indicator that may assess this condition, there were evaluated activities and projects in both NPAs, resulting in:

Implemented actions related to local needs:

The number of actions in relation to the local needs divided by the total actions and multiplied by 100. For LT was 27.7% and LP 66.5%

Implemented actions directed to conservation:

The number of actions oriented to conservation divided by the total implemented actions multiplied by 100. For LT was 27.1% and LP was 15.3%

Furthermore, in the above analysed, the presence, physically and symbolically, of the NPA management office, where one depends on the other, was considered important to evaluate. As it was previously mentioned, there are lacks on communications, which result in a weak or null social presence, results obtained through the fieldwork and interviews. Physically, through the use of geographical information systems with ArcGis 10 and the INEGI's series 5 related to soil and vegetation information, it was observed a weak presence of both NPA management office on field, attending/working with a minuscule number of localities in relation to the total located on the NPA and its influence zone (Figs. 1.5 and 1.6). Results showed that the influence zone of the LT NPA comprehends 1139 communities (INEGI 2010), and for 20 years the management office has only attended 54 of them (Fig. 1.5). Meanwhile, in LP, there are 85 communities, and for 10 years, only 21 have received some attention (Fig. 1.6).

The physical presence was related to the land use structure for assessing the level of successful interventions and management actions to preserve the vegetation coverage in each one of the NPA, it was found besides the weak physical presence of both NPA management offices an extreme focalization, where three or four localities on each NPA have received half of the ICDP projects (Figs. 1.7 and 1.8).

It is also evident the changes in the vegetation coverage can be appreciated where grasses are present, giving evidence of illegal logging and livestock activities. In regard to the livestock activities, there was no activity nor project implemented on either NPA, even though this is established on both management programmes as an activity that requires attention for reducing its impacts. At the same time, Figs. 1.7 and 1.8 show dramatic changes in vegetation coverage in the influence zone, especially for agriculture – creole maize – and livestock purposes.

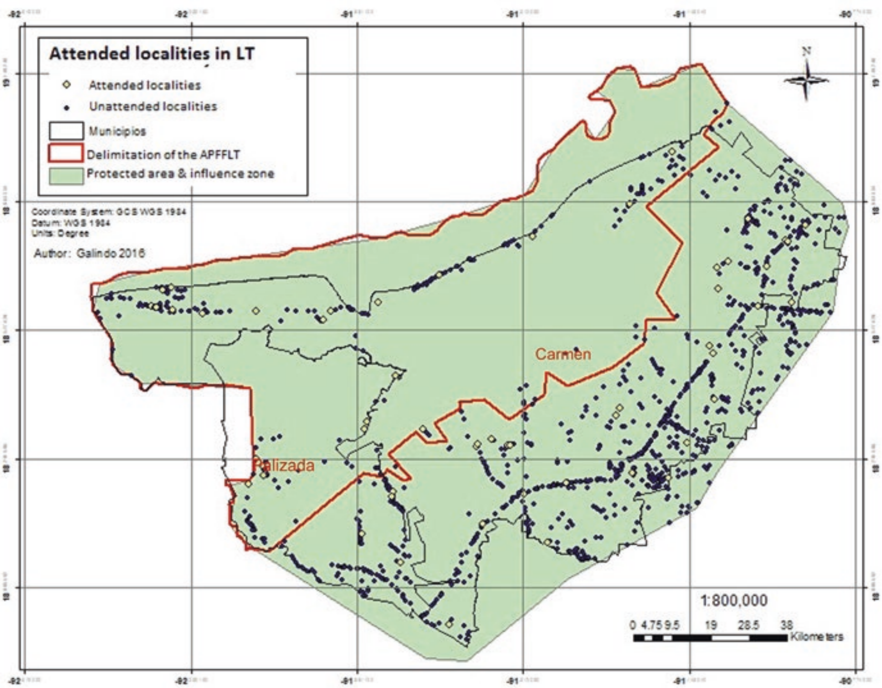

Fig. 1.5 Attended communities by the management office of LT NPA. (Source: INEGI 2010; SIG de CONANP; and IFAI)

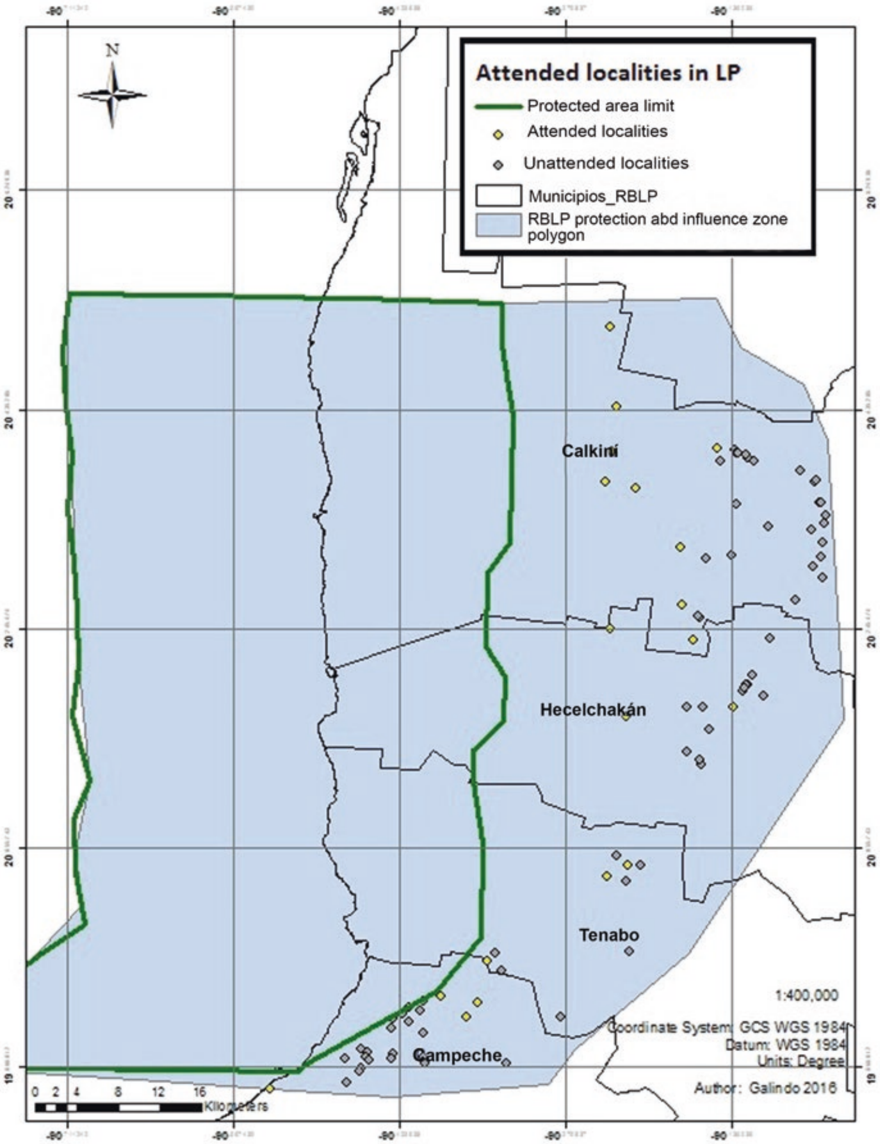

Fig. 1.6 Attended communities by the management office of LP NPA. (Source: INEGI 2010; SIG de CONANP; and IFAI)

As it was said, the extremely focalized attention on both NPAs has implications on the social presence of the NPA management office and of the ideal of conservation. Even though there are several differences between the kinds and diversity of projects implemented on each NPA; at LT the efforts have a diversified characteristic, where orchards, restoration, aquaculture and tourism were the kind of projects

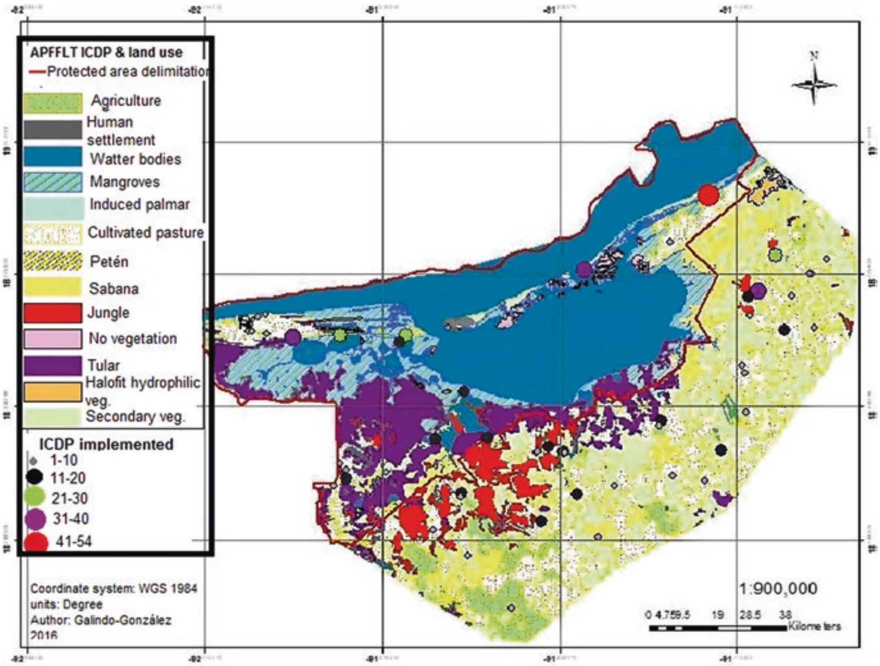

Fig. 1.7 Changes in vegetation coverage in LT. (Source: INEGI 2010; Carta de Uso de Suelo y Vegetación de INEGI Serie V; SIG de CONANP)

that receive more attention; however on fieldwork it was observed that just tourism and restoration are part of the socially organized initiatives. Hence, are important to notice, on field, the different social interventions and activities developed, since results of ICDPs would be better when the projects are related to benefited people activities (Muttulingam & Shen 1999) (Figs. 1.9 and 1.10).

In regard to the projects implemented on LP, it was found that creole maize and resource transformation projects received most of the attention. Even though it could be said that creole maize projects have good intentions in preserving the huge variety of maize, the programme required a connectivity with the economic and agriculture politics, which would give sense to the programme aim. Also, this lack of inter-sectoral communication was found in the resource transformation projects, which attend handcraft producers, who through the ICDP implementation have improved their productivity, but this has not been traduced on the improvement of their well-being, since they have lot of issues in the sales stage and many others.

Assessing ICDP effectiveness, it is evident that it is negatively affected by their scope and institutional capacity, the suitability to address current local communities' needs and the budget allocation and the efficient use of it.

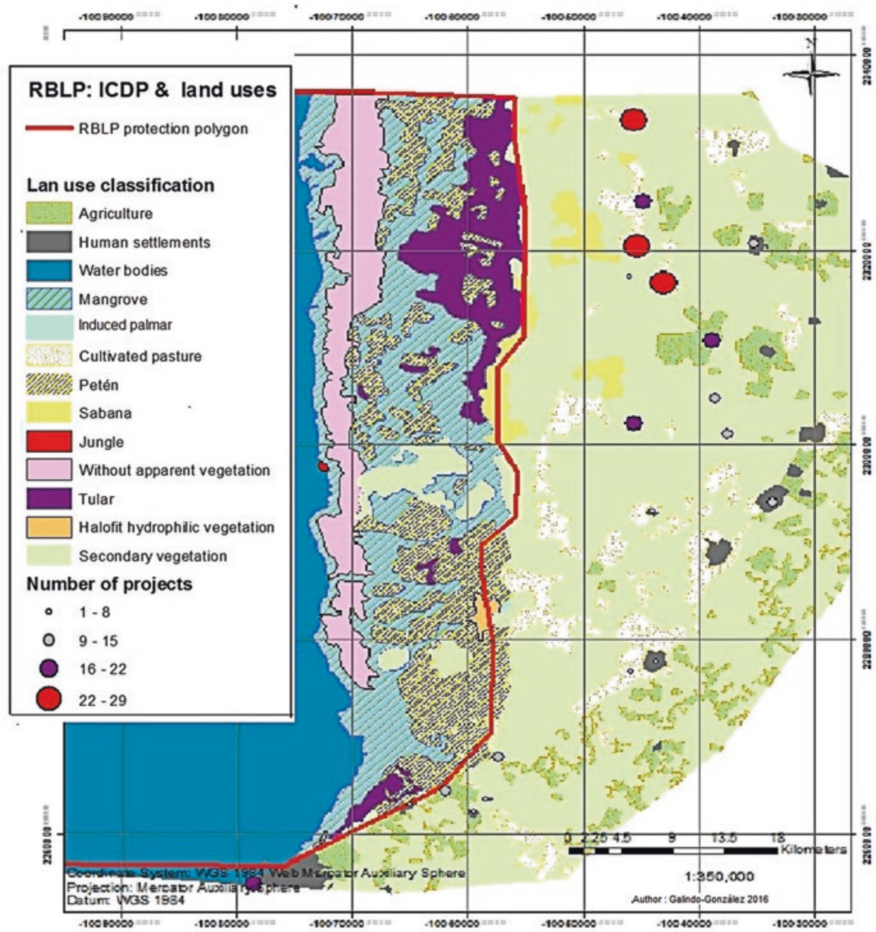

Fig. 1.8 Vegetation coverage changes during the 2009–2015 period in LP. (Sources: INEGI 2010; Carta de Uso de Suelo y Vegetación de INEGI Serie V; SIG de CONANP, and IFAI)

1.3.5 Biodiversity Conservation Status

During the decade of the 1970s and 1980s, the richness of species in LT accounted 154 fish species, 83 crustacean species and 176 molluscs species. Yáñez-Arancibia et al. (2005) reported 121 fish species, while Ayala-Pérez (2003) and Ramos-Miranda et al. (2005) reported 105–107 fish species. Ramos-Miranda and Villalobos-Zapata (2015) presented a summary of studies from 1980 to 2011 where according to her analysis, the richness, abundance and biomass of fish species have decreased (Table 1.10).

The same tendency has been shown by seagrasses in LT where Herrera-Silveira et al. (2011) reported a decrement from 60% to less than 30% inside the lagoon.

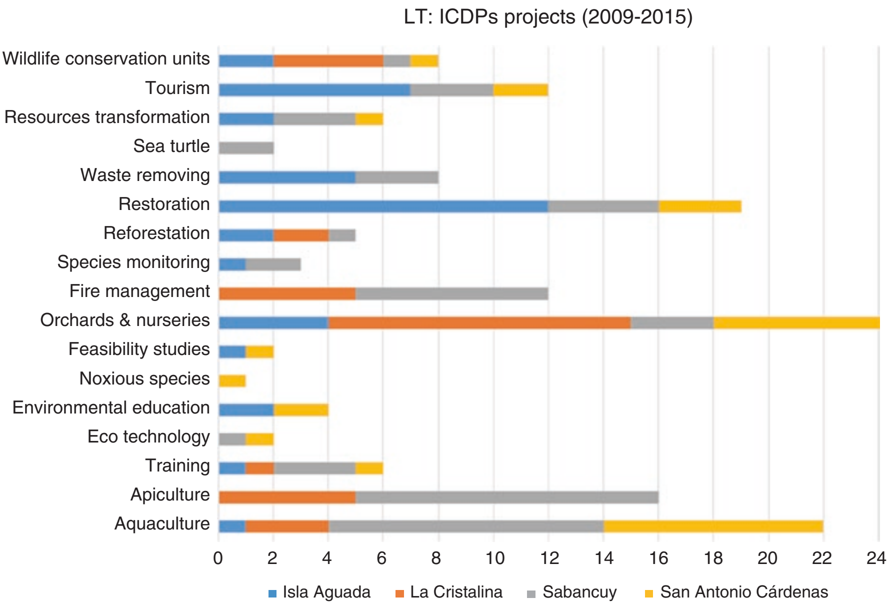

Fig. 1.9 ICDP activities in LT during the 2009–2015 period. (Source: IFAI)

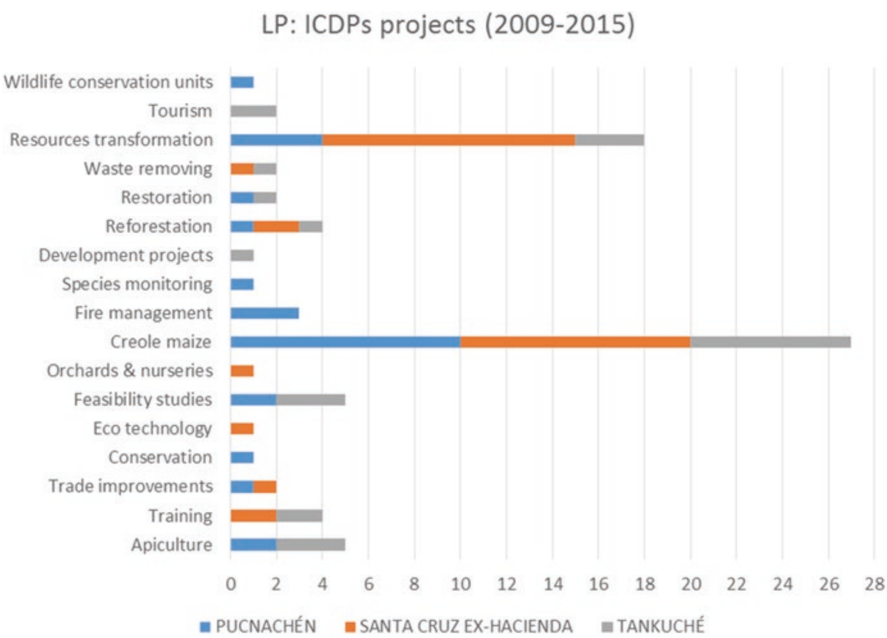

Fig. 1.10 ICDP activities in LP during the 2009–2015 period. (Source: IFAI)

Table 1.10 Changes in abundance and biomass of fish species in LT

Years	Abundance	Biomass
1980–1981	52.1+5.1	2103.6+257.5
1998–1999	78.6+7.6	1743.1+136.7
2010–2011	30.8+3.0	887.2+64.4

Source: Ramos Miranda and Villalobos-Zapata (2015)

Table 1.11 Heavy metal concentrations in LT sediments

Heavy metals in LT				
Author	Year of the study	Cd (ppm)	Pb (ppm)	Ni (ppm)
Botello (1986)	1985	1.5	42.5	50.9
De la Cruz Landero et al. (2013)	2011	0.75	16.05	82
Limits stated by NOM 1996		0.2	0.4	4

However, marine biodiversity has not suffered changes; according to the management plan in 2006 and other authors (Vega-Rodríguez et al. 2013; Muñoz-Rojas et al. 2013), there are 47 species of fishes.

Water quality has been an issue in both NPAs, especially runoffs coming from agriculture fields surrounding LT and LP. Studies made by Morales and Cobos-Gasca (2005) and González-Jáuregui (2008) discovered the presence of DDT and DDE in marine turtles' eggs, as well as agrochemicals in eggs of *Crocodylus moreletii.* A major source of water contaminants in LT are persistent organic compounds, such as HCHs, HCBs, Drines, DDTs and PCBs (Gold et al. 2010). And Botello (1986) has also identified heavy metals such as Cu, Ni, Co, Cr, Pb, Cd and Zn, mentioning that in 10 years, concentrations of these contaminants have increased 50% (Table 1.11).

In 1993, LT had 10.7% of the mangroves of the country (De la Lara et al. 1993). However, between 1990 and 2010, there was a loss of 6945 ha of mangroves in LT (Agraz-Hernández 2012). On the other hand, LP lost 1412.74 ha of mangroves from 2005 to 2010 (Figs. 1.11 and 1.12).

1.3.6 NPA Effectiveness for Nagoya Protocol and Aichi Targets Implementation

As stated earlier in this chapter, the NP established that each party should define (a) the fair and equitable sharing of the benefits arising from the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies and (b) by appropriate funding, thereby contributing to the conservation of biological diversity and the sustainable use of its components (Nagoya Protocol 2011).

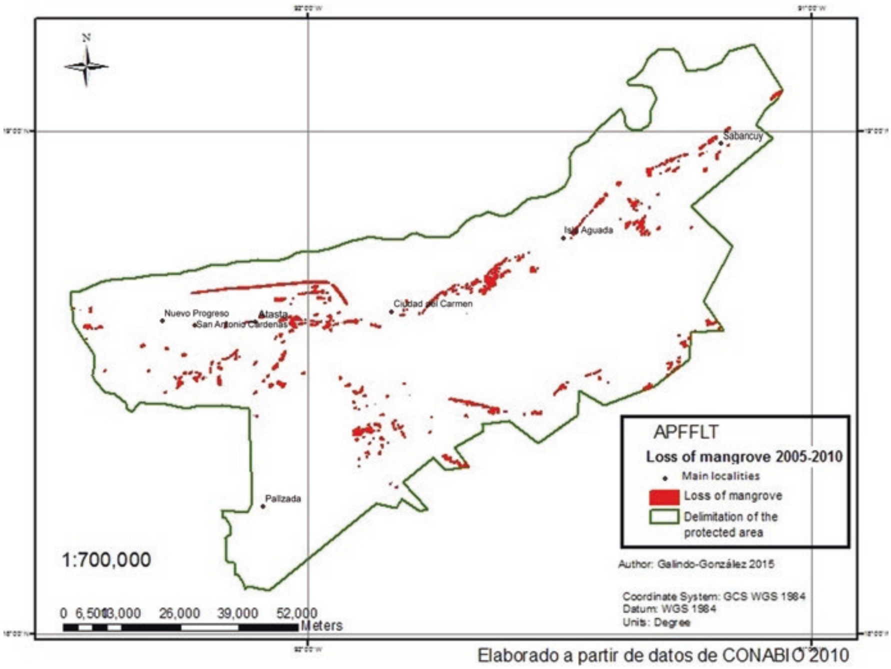

Fig. 1.11 Mangrove loss in LT (1990–2010). (Source: CONABIO 2013)

An important component to ensure the implementation of both instruments, the NP and the AT, is the Mexican institutional framework that should be involved, according to the legal and political current framework, which requires a complex interinstitutional interaction (Fig. 1.13).

Figure 1.13 shows the federal institutions over the dotted line, which are the ones that have to interact at some level with the international mirror institutions for NP implementation, learning, exchanging lessons learned, etc. An important gap is the governmental organism (CIBIOGEM) in charge of biosafety and genetically modified organisms (GOM) that does not function properly. In this figure, it is also recognizable conflicts that start with the ownership of the natural resources and ecosystems themselves. According to Article 27 of the Mexican Constitution, all natural resources and ecosystems belong to the nation, which explains the intervention of the benefit distribution and richness allocation (Tagle 2009), in an attempt to avoid monopolies and preserve territorial reservoirs for the public good, accounted as natural capital that conforms to the economic sustainability of the country and that takes into account market and non-market values (Gómez 1998).

This is a different approach from the Agreement 169 of the Indigenous and Tribal People Convention and the Inter-American Commission of Human Rights (2009), which have ancient background in Mexico, such as the "Título Primordial" granted by Viceroy Mendoza in 1539 in Mezcala Jalisco, Mexico (Bastos 2011), recognizing the territory of these indigenous people as their own for their use and exploitation.

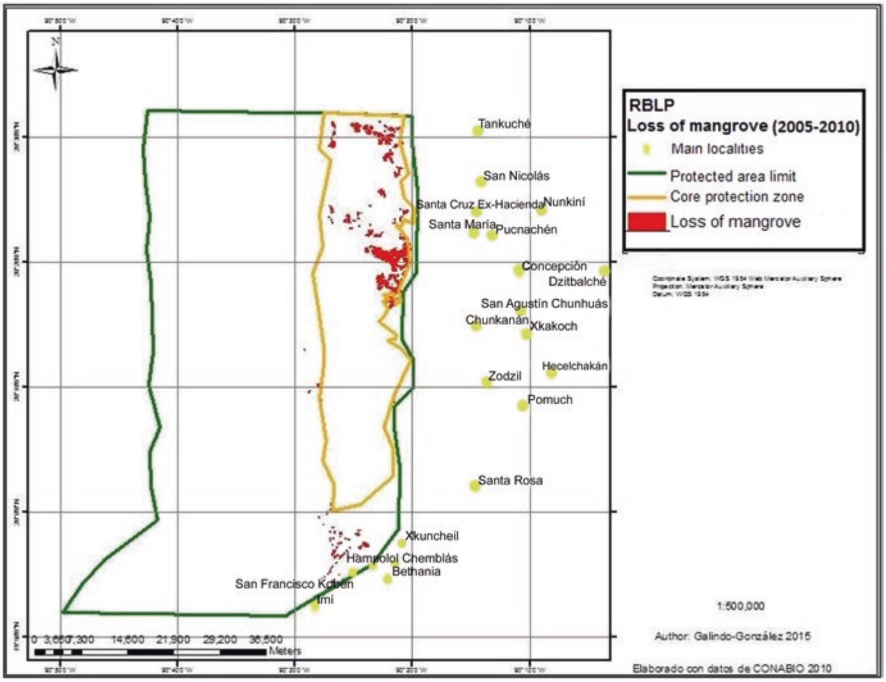

Fig. 1.12 Mangrove loss in LP 2005–2010. (Source: CONABIO 2013)

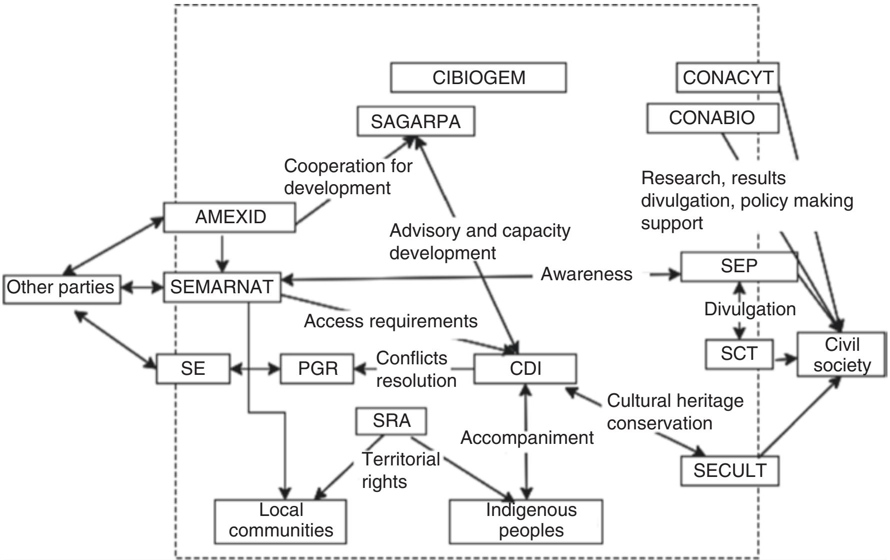

Fig. 1.13 Interinstitutional complex interaction for NP and AT implementation in Mexico. (Source: Galindo-González 2016)

The main conflict is the acknowledgement of property rights – land and natural resources – of indigenous people and local communities under the current legal framework.

Another issue is the one linked to agriculture and technological packages promoted by the federal government for GOM crops. However, indigenous people recognized a link among seeds and their autonomy and productive sovereignty (Navarro 2013). Current government has made a public consult about GOM; nevertheless, several authors (Pérez 2016; Ribeiro 2016; Rojas 2016) consider that CIBIOGEM has a biased action which has been unfavourable to indigenous people and local communities. The GOM distribution in indigenous people is grave, because domestication processes derived from their traditional knowledge took place (Ituarte-Lima 2004). And all this has much more weight considering that Mexico is the centre origin of 15.4% of the main species used at global level for food purposes (CONABIO 2006).

A fair and equitable distribution of benefits is addressed in Article 87bis of the General Environmental Protection Law, but it is only for collecting items for biotechnology purposes; meanwhile scientific collection does not reattribute any benefit to the owners. Within NPAs, the benefits and sharing mechanisms would be decided according to the management programme. However, in the ejidos, the highest decision-making organ is the general assembly, and the federal government recognizes the freedom and autonomy of indigenous and local communities to decide upon their social and economic organization, political structure and cultural and traditional behaviour (Art. 2 Mexican Constitution). The governmental institution in charge of the indigenous people rights is the CDI.

As looking again at Fig. 1.13, there have been several important steps towards the integration and recognition of indigenous people's rights; together with CDI (2011) there are others such as the SER, SEMARNAT, SAGARPA, SS, CONABIO, IMPI, CONACULTA, INDAUTOR, INALI and SEDESOL, which require the big effort from the Mexican government to implement the NP and the AT.

Benefit sharing is the most difficult of all because it implies administrative apparatus and surveillance mechanisms that are too expensive. Almost all scientific scientific activities performed within the NPAs do not have any contact with the management office (Alarcón 2010), so they are ignorant of the resource collecting, the biological material sampled, the cultural and traditional methods research, nor the implications and objectives, sources of funding nor any useful information that may give NPAs the possibility to track down resources-benefits allocation.

As early stated, there are 20 AT, and the capacity of the Mexican government for attending each one of them is summarized in Table 1.12.

The SWOT analysis would complete this assessment, considering that the first two dimensions (strengths and weaknesses) are internal and the last two (opportunities and threats) are external to the NPAs. The SWOT analysis used all the previous information of this chapter to identify positive and negative factors within the organization, the environment and especially the biodiversity and the local communities. This analysis was made for the AT and the NP in Table 1.13.

Table 1.12 Governmental capacity to address Aichi Targets

Institution	Aichi Targets																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SEMARNAT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CONANP	X		X	X	X				X		X			X				X		X
CONAFOR			X	X	X									X					X	X
CONAGUA				X				X						X						
CONABIO												X							X	X
INECC															X					
SAGARPA			X	X	X	X	X	X	X			X	X		X			X		
INAPESCA				X		X														
CONAPESCA						X														
CIBIOGEM									X											
SRA			X												X					
SEGOB								X												
SE			X	X				X	X						X					
SER								X								X				
SCFI								X												
SEP	X														X					
CONACYT	X																		X	
SENER			X					X							X					
SCT	X		X					X		X					X					
STPS	X																			
INEGI		X																		X
SHCP			X												X					X
SEMAR			X					X		X										
SS			X					X						X	X					
SEDESOL			X											X	X					
CDI				X									X	X		X		X		
SEDATU				X																
SECTUR								X												
SECULT																		X		
PROFEPA			X	X				X		X		X			X					
Ministerio Público			X	X																

Source: Galindo-González 2016

Table 1.13 SWOT analysis for assessing the effectiveness of NPAs for implementing NP and AT

Strengths	Weaknesses	Opportunities	Threats
Strong legal environmental framework	Poor institutional capacity and worse budget allocation	Improvement of the management plan and management office effectiveness	Insufficient budget allocated to the CNAP and NPAs
Strong natural capital and ecosystem services	Poor administration and planning, and ineffective decision-making process	International collaboration and cooperation building	Unknown climate change effects on biodiversity and ecosystems
Joint efforts at cross-cutting sectors, as vertical and horizontal governmental levels	Loss of biodiversity and ecosystems	NPAs may acquire the decree to be acknowledged as genetic diversity centres	Externalities that impact the NPA, such as agriculture, and invasive exotic species
NPAs are the genetic reserves as cultural heritage reservoir	Poor actualized scientific knowledge about the biodiversity and ecosystems in each NPA	Biological corridors to link different NPAs, improve ecosystems connectivity and other biological conservation strategies should be implemented	Biopiracy is rampant without any institution addressing the situation

1.4 Conclusion

1. The key factor for a successful implementation of the AT and the NP is the reviewed and actualized NPA management programme that includes critical paths to address, implement and evaluate AT and NP.
2. Administrative support is urgently required at local level at each NPA management office; this includes accountability and legal aid.
3. Biodiversity loss and ecosystems damage are evident in both NPAs, especially in LT. Surveillance and local involvement is crucial to support the CNPA efforts for conservation.
4. Illegal fisheries, logging and fires have to be deterred through appropriate mechanisms and collaboration from all involved parts.
5. Poor planning results in a number of problems including poor effectiveness; but decision-making processes inside the management office and at the highest level of the CNPA also are contributing to the lack of effectiveness. This should be reviewed.
6. Insufficient budget is a major problem to achieve new objectives and goals. But this is worse by poor capacity, lack of monitoring and duplication of activities and programmes.

7. It would be important that each NPA promotes more cooperation and collaboration at international level for seeking funding, capacity building and lessons learned exchange.
8. Social perception about the CNPA is a funding agency, rather than a conservation organization. This generates a pressure that does not help NPA's purpose. Also, this denotes the inter-sectoral efforts that need to be taken for solving complexity territorial issues as marginalization and poverty.
9. LT requires more attention to fisheries' biodiversity, much more now that PEMEX has closed many sources of employment in the region, while LP should pay attention to regulate sea cucumber and octopus fisheries and the handcrafts' larger group that use biological regional materials to make hats, hammocks and roofs that are scarce now.
10. The final conclusion is that NPAs have the potential to fulfil the AT and the NP requirements because of the strong Mexican legal framework. However, the implementation has a red alert since the local capacity jeopardizes the successful achievement of goals and targets.

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Chapter 2
Are Current Actions for Conservation in Mexico Enough? A Review of the Proximate and Ultimate Threats

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Abstract Mexico is a mega-diverse country with a high percentage of endemic and threatened species. Biodiversity conservation and the maintenance of ecosystems functions must be a national priority. In this chapter, we present some examples at Mexico environmental transformation or resource use strategies, which had constituted direct or indirect threats to species and ecosystems conservation. We highlight the importance of considering the socio-ecological system approach to prevent species' loss, environmental deterioration and to ensure the well-being of human societies.

Keywords Extinction risk · Extinction vortex · Habitat loss · Invasive species · Socioecological systems

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2.1 Introduction

Some scientists have proposed that our planet is at a new geological era named Anthropocene and people are beginning to raise awareness about the consequences of human alterations to the Earth's ecosystems (Crutzen 2002). These changes threaten the future of biodiversity, the functionality of ecosystems, and the well-being of human societies. To face this problem, we need to stop the loss of species, avoid environmental deterioration, develop knowledge, and generate new policies.

Minimum viable population sizes model (PMV) was one of the first theoretical models implemented to ensure the persistence of species over time. This model estimates the minimal effective size (N_e) that requires one population to guarantee its persistence over a long-term period (e.g., 100 years). For instance, the minimum effective population sizes (N_e) for a population of dioic organisms could be between 1000 and 10,000 individuals (Meffe et al. 1994).

Gilpin and Soulé (1986) presented a theoretical model which shows how the interaction of different variables can lead a population to an extinction vortex (EV). Among these variables are the population size, population subdivision, genetic variability, inbreeding depression, and fitness, which can produce feedback loops over the other variables. In this sense, populations can arrive in an extinction vortex due to (a) a strong stochastic oscillation in population sizes, (b) a reduction in the genetic variation, (c) an increase in inbreeding, and (d) a decrease in the fitness of the population. The relative importance of these variables increases as populations decrease, thus increasing the likelihood of extinction (Brook et al. 2008; Caughley 1994) (Fig. 2.1).

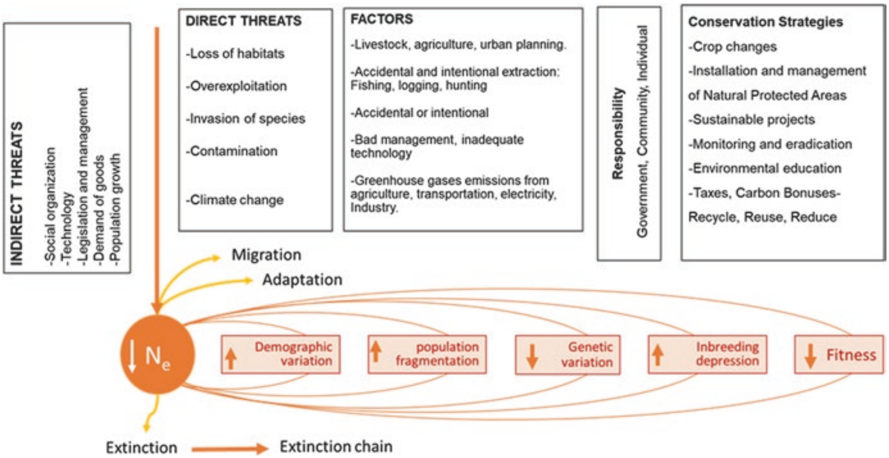

Fig. 2.1 Extinction vortex model and the direct and indirect threats. The population or species extinction occurs when the effective population size (Ne = adult breeding) decreases, causing a synergistic action of several genetic and demographic processes that affect the adequacy of the population (Modified from Gilpin and Soulé 1986). Also the responsibility agents as the conservation strategies that can be used to avoid the impact of these threats are shown

Fagan and Holmes (2006) studying the dynamics of several species of vertebrates that ended up becoming extinct verified what was predicted by the theory of extinction vortices. In addition, they found that the rate of change of these variables increased as populations decreased in size, making small populations more prone to extinction.

The disappearance of a species not only constitutes a specific loss within a community, but it can lead to a chain of extinctions within the communities, altering not only the functionality of the ecosystem but also the goods and services that societies obtain from them (Navia et al. 2016).

Mexico is a mega-diverse country due to biogeographical factors (overlap of the Nearctic and Neotropical regions) and its intricate relief and the great variety of soils and climates. Although the Mexican territory is only 1.4% of the planet's surface, it hosts between 10% and 12% of the known species. Remarkably, many of the species found in Mexico are endemic (i.e., 30% of their mammal species, between 9% and 25% of their birds, 50% of their reptiles, 64% of their amphibians, and 10% of fish). The high biological diversity also is correlated with a high cultural diversity expressed in its 291 living languages. The disappearance of Mexican diversity would be regrettable. Therefore, conserving the Mexican biodiversity and the functionality of its ecosystems is essential (Sarukhán et al. 2009; Jiménez et al. 2010).

Mexico, like other nations, has transformed its natural environments to obtain diverse biotic and abiotic resources. The acquisition and transformation of these resources produce environmental costs, such as the loss of vegetation cover; the alteration of CO_2 fixation and the supply of O_2 by plants; the alteration of climates, hydrological cycles, and the nutrients; as well as the loss of a natural reservoir of pollinators, many of which are useful for domestic species. All these environmental costs lead to the loss of biodiversity, decreasing the ecosystem goods and services to finally impact human well-being (Challenger and Dirzo 2009).

To understand the pressures to which ecosystems are subject, it is useful to identify which are the direct threats (and their causes) and which are the indirect or ultimate threats that will generate these changes (Primack and Sher 2016; Primack et al. 2006). Notably, it is important to visualize who are the actors and their behaviors, as well as the social instances that can help to prevent the loss of biodiversity and ensure the achievement of long-term social welfare.

2.2 Proximal or Direct Threats to Biodiversity

The proximate or direct threats of transformation of the natural ecosystems are (a) the loss of habitats, (b) overexploitation of organisms, (c) the introduction of exotic species, (d) the addition of polluting products, and (e) anthropogenic climate change. These threats do not act alone. Instead, they work in synergy and with feedback mechanisms that alter the functioning of ecosystems and complicate mitigation measures (Primack and Sher 2016) (Fig. 2.1).

2.2.1 Loss of Habitats

The destruction of natural environments in Mexico is alarming. In 2002, 62% of the national territory had already lost its primary vegetation, and the remaining is fragmented and with several degrees of disturbance. Tropical regions have been disturbed the most. For example, humid forests have lost more than 80% of their original coverage, especially since the 1970s of the last century, due to agricultural production, construction of dams for the irrigation of monocultures, and the distribution of "idle" lands. Wetlands or semiaquatic environments had also been altered or disappeared. For example, in the Comarca Lagunera in the Northern Mexico, 92 springs have dried up, and 2500 km of rivers have disappeared. The Mexican government promoted all of these land conversion (Challenger and Dirzo 2009).

Alteration of vegetation leads to the loss of animal diversity, changes in climate, increased erosion, loss of soils, and impact on ecosystem services such as carbon dioxide capture, oxygen release, soil fertility, and the abundance of pollinators, among others.

The causes of changes in land use were due to (1) agricultural purposes (13% of Mexico's tree cover disappeared), (2) livestock purposes (49%), and (3) urban growth (towns and cities) (Masera et al. 1995).

2.2.2 Overexploitation or Extraction of Organisms

This factor refers to the obtaining of biological resources directly from the natural environment. Among the most notorious overexploited industry in Mexico is fishing and the extraction of precious woods.

Mexico has a large area of coasts and is the sixteenth country in the world in fisheries production. However, 60% of their management units have already reached their maximum yield, and 26.6% have overexploitation (Sagarpa 2004) so that 86.6% of marine fishing units cannot suffer increases and measures of management and protection are needed. A similar situation is found in some coastal lagoons since shrimp and oyster populations have been reduced notably (Olmsted 1993; López Portillo and Ezcurra 2002; Casasola et al. 2002; Carrera and de la Fuente 2003).

Sea exploitation alters the composition not only of human-used species but also of other species which are caught incidentally in the fishing nets. The situation of the marine vaquita (*Phocoena sinus*), an endemic marine cetacean of the northern region of the Gulf of California, is alarming, as it is about to disappear. Although the sea dynamics of the north of the Gulf of California changed since the installation of the Hoover Dam in the Colorado River in 1936, it seems that the critical situation of the vaquita marina relies on its incidental catch in the search for totoaba or white croaker (*Totoaba macdonaldi*), which is endemic to this region and which has great economic value due to its use in Chinese cooking (Rojas-Bracho et al. 2006; Taylor et al. 2016, 2017).

2.2.3 Invasive Species

The introduction of foreign species to natural ecosystems can cause the displacement of native species and even produce a change in the dynamics of natural ecosystems. The effect of the introduction will depend on the invasiveness of the species and the characteristics of the environments, since in isolated environments such as islands and lagoons, the effects are generally more severe than in less isolated environments (Primack and Sher 2016).

For example, in the small lagoon Chichancanab (located in the central west of the state of Quintana Roo), changes were registered in the biota of the indigenous endemic fishes of the Cypriodon group and the poeciliid (*Gambusia sexradiata*) due to the arrival of a species of African cichlid fish (genus *Oreochromis*) in 1989 and a Mexican fish *Astyanax fasciatus* (Characidae). The displacement of the native species, apparently, was due to the predatory behavior of the introduced fish and the introduction of parasitic species (trematodes and nematodes) of the exotic fish that took as host the native fish species (Strecker 2006).

Another example, with great socioeconomic impact, is the introduction of the devil fish or plecos, *Pterygoplichthys pardalis* (of the Loricariidae family) to various bodies of freshwater in Mexico. *P. pardalis* is a freshwater species, native to South America and to the Amazon River basin, which has invaded several regions of the world, some as distant as the Indochina peninsula. In all cases, the introduction mechanism has been produced by the aquarium market and its escape from aquaculture farms. In Mexico, the first record of these exotic fish was in 1995, on the Mezcala River (Guerrero). Currently, the species is distributed in several freshwater bodies of the states of Michoacán (Infiernillo Dam and Balsas River), Chiapas, Campeche, Tabasco (Pantanos de Centla and Grijalva River), Morelos, Guerrero, Jalisco, Sinaloa, and Veracruz (Amador del Angel et al. 2014).

The success of the plecos as an invasive species is due to its physiological characteristics, since it can resist low oxygen concentrations by breathing atmospheric oxygen and can tolerate up to 30 h out of the water. In addition, it resists diverse salinities and low water quality. It feeds on plants and debris from sediments, as well as from organisms and fish eggs found in sediments. Its introduction is considered to be one of the greatest threats to the biodiversity of continental aquatic ecosystems (Mendoza-Carranza et al. 2008), since they produce destruction and instability of the coastline and erosion of reservoirs and channels, due to the formation of burrows and tunnels in the sediment. Its introduction alters the dynamics of trophic chains and competes with native fish. The socioeconomic problem, specifically in fisheries, is due to the entangled of the exotic fish in the fishing nets, causing losses in the capture of fishes of commercial importance. In addition, they have displaced native species of commercial importance because their abundance is increasing (Hernández 2008; Barba-Macias et al. 2014).

In terrestrial ecosystems of Mexico, there is also evidence of invasive plants that have changed the dynamics of natural ecosystems. An example of this is the invasion by buffelgrass grass (*Cenchrus ciliaris*) in Northwest Mexico. The species is a perennial grass native to tropical Eurasia that has been introduced in livestock areas as a forage plant due to its nutritional value and its desirability characteristics that make it attractive to livestock. In addition, it is resistant to prolonged droughts and has a habit of aggressive growth, which allows it to produce 2–20 times more fodder than native rangelands. However, the species has become wild and has spread covering large areas, changing the microenvironmental conditions of the soil, and affecting the structure of the natural communities of the semidesert zone of the Sonoran Desert. Its presence constitutes a risk for the environment, since when dry it causes extensive fires. This grass has invaded areas inhabited by cacti, many of which are endemic, and is known to affect the development of small globose populations, as has been reported with populations of *Mammillaria grahamii* in the northern part of the country (Bracamonte et al. 2017).

2.2.4 Pollutants

A pollutant is any substance, physical element, or exogenous energy introduced into a system, thereby decreasing the quality of the environment. The amount and variety of pollutants that are introduced to the environment today are very varied, and this incorporation has been accelerated by industrial activity, trade, and increased consumption of various goods.

Here, to cite an example, we will refer to the use of organochlorine chemical compounds which have been introduced into nature through the preparation and application of herbicides, pesticides, and fertilizers, which are made with the purpose of increasing the yields of agriculture of monocultures. These compounds alter not only the local ecosystems, but they are carried to the bodies of water, concentrating through a trophic chain. Its effect on nature has been recognized since the 1960s from the classic book *Silent Spring* by Rachel Carson, and the consequences of its use have now been verified by the lamentable crisis of pollinators and the decline of the biomass of the insects in various parts of the world (Kearns et al. 1998; Hallmann et al. 2017).

The organochlorine compounds are constituted by a skeleton of carbon atoms, in which some of the hydrogen atoms attached to the carbon have been replaced by chlorine atoms. Among these compounds are DDT, dicofol, heptachlor, endosulfan, chlordane, aldrin, dieldrin, endrin, mirex, and pentachlorophenol. Many of which have been banned in several countries, although in tropical countries they are continuously used for the control of tropical pests. Their toxicity affects the overall heath of the organism including its metabolism (e.g. lipid metabolism, transport of vitimins and glucose) and its immunological responses and reproductive function (Prado et al. 1998).

In Mexico, the use of these compounds is legislated by several laws, norms, and instances that make the practical regulation of them complex. In 1998, Prado and collaborators detected the permanence of organochlorine pesticide residues in pasteurized milk sold in Mexico City that exceeded the maximum allowed limits of various compounds such as lindane, aldrin, dieldrin, heptachlor * heptachlor epoxide, endrin, and DDT. The presence of these compounds in biotic and abiotic substrates is due to their physicochemical properties of persistence, lip solubility, and bioaccumulation as well as the excessive use of these compounds in agricultural practices and in the control of diseases transmitted by insects. In relation to cattle, the main causes of their contamination with organochlorine pesticide residues are (1) the consumption of foods that have been treated with these compounds (pasture, hay, concentrate, and silage, among others), (2) the use of chemicals to control livestock parasites, (3) use of compounds to control insects in the stables, and (4) environmental pollution (water, air, soil), among others (Pinto 1990).

2.2.5 Climate Change

Greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorinated hydrocarbons (PFC), and sulfur hexafluoride (SF_6) have the property of retaining the atmospheric heat (infrared light) which contributes to the global warming of the planet. The increase in the average temperature of the planet leads to an alteration in other climatic variables such as rain regimes and cyclone frequencies.

In Mexico, like other countries, CO_2 emissions have increased since the beginning of the industrial revolution (nineteenth century). According to the National Inventory of Emissions of Gases and Greenhouse Compounds (2013), the carbon dioxide (CO_2) emissions derived from the use and burning of fossil fuels represented 1.37% of global emissions in 2012, which places Mexico in the thirteenth spot among countries with the largest volumes of these gas emissions (INEC 2014).

Direct emissions of GHGs in the country amounted to 665 megatons of CO_2, of which most are due to the transport sector (26%), followed by electricity generation (19%) and the industry (17%). In the case of black carbon, a short-lived climate pollutant (CCVC), its volume of emission reached around 125,000 tons, derived mostly from the activities of the transport sector (38%) and industrial, mainly the sugar subsector (28%) (INECC 2014).

Deforestation is another cause of CO_2 emission into the atmosphere, as trees from forests and jungles act as an important reservoir of CO_2. The felling of the trees and the installation of herbaceous crops in their place cause these reservoirs to be lost. In addition, when the soil is left without the protection of vegetation cover, the decomposition of the organic matter in them is accelerated, releasing CO_2 to the atmosphere.

In Mexico, the acceleration of the release of CO_2 into the atmosphere was notorious since the middle of the twentieth century, due to government policies aimed at deforestation and the distribution of land for agricultural purposes, also causing the degradation of fertile soils (Challenger and Dirzo 2009).

At that time, deforestation in southeastern Mexico (Quintana Roo, Campeche, and Yucatán) was alarming, and several well-known Mexican biologists, including

Dr. Barrera and Dr. Gómez-Pompa (Barrera 1982), expressed their concern about the management of forest and jungles' wealth in different regions of the country that were subjected to great destruction. Edwards (1986) estimated that about 184,000 ha had been dismantled in the state of Quintana Roo, and if this trend continues, the forests would end up being eradicated from Mexico. In the south part of the Yucatán Peninsula, for example, the federal government, through the Interministerial Commission of Ejidal Colonization, had a great influence in financing the transfer of the local people and their settlements in this region. The process included the deforestation of the jungles to start up collective systems of mechanized agriculture and livestock of bovines. However, many of the areas originally destined to corn cultivation failed because the soils had slow drainage and clay texture. Then, these crops were replaced by paddy fields. But, the irregularity of the rains, the invasion of Johnson grass (*Sorghum halepense* (L.) Pers,) which is an invasive species of Mediterranean origin (Conabio 2009), as well as the requirements of agrochemicals to control the incidence of pests and diseases of rice made this crop not profitable, which caused the lands to be abandoned or intended for livestock.

Apparently, the great deforestation of the Mexican southeast began to diminish between 1982 and 1983, coinciding with a national economic crisis, as well as the formation of groups of ejidatarios (farmers) who disagreed with deforestation companies (Cortina Villar et al. 1998). Before these dates, there were public and private companies that had concessions to take advantage of large areas of forest under the shelter of the law (National Forestry Law of 1945), which decreed that it was necessary to establish "forest exploitation units" in forested areas. These units were established by presidential decree, and then, large areas of forest were monopolized. In the south part of Quintana Roo, for example, the company "Maderas industrializadas de Quintana Roo" (MIQRO) had the concession for 29 years to exploit ejidos forest resources, even though the ejidatarios were the legitimate owners (Cortina Villar et al. 1998).

Methane is another important GHG, which, although in very low concentrations in the atmosphere, contributes significantly to the global warming of the planet by having a global warming potential of 23, which means that in a measure of time of 100 years, each kg of CH_4 heats the Earth 23 times more than the same mass of CO_2 (IPCC 1997).

In the last decades, methane emission into the atmosphere has increased worldwide. This is due both to increase in rice planting and the increase in cattle farming. In the soils of the rice fields, the anaerobic decomposition of the organic matter by anaerobic bacteria is propitiated, with which methane is released as a by-product. The same is true for the bacterial activity in the digestive tract of cattle, which has increased worldwide to cover a growing market demand for both meat and milk. In Mexico, however, rice production has remained more or less stable in the last 10 years with around 0.17 million tons/year, which has implied a deficit in relation to the demand of a growing national population. This deficit is reflected in the increase in the import of this rice in this same period of time, from 0.57 to 0.75 million tons/year (FAO 2011). With regard to bovine production in Mexico, this has only increased slightly between the year 2000, in which there was a production of 30,523,700 heads/year to 32,939,529 heads/year in 2014 (FAO 2015).

Currently Mexico has begun to develop a policy to face the problem of GHG release and fulfill its responsibility under the agreements of the Climate Change Convention. Among the advances are the approval of the General Law of Climate Change (LGCC) in 2012 and the creation of the National Institute of Ecology and Climate Change (INECC 2014), as well as the implementation of the National Climate Change Strategy 10-20-40 Vision and the Special Climate Change Program (PECC 2014–2018). There is also a system for monitoring the release of CO_2 into the atmosphere, and a payment for services system has been established. In addition, there is a discussion to develop a policy to protect the population from the effects of climate change (extreme hydrometeorological phenomena) and to promote the resilience of the country's strategic infrastructure and the ecosystems that host biodiversity and provide important environmental services (INECC 2014).

2.3 Ultimate or Indirect Threats to Biodiversity

Indirect or ultimate threats to biodiversity (also called root threats) include social, economic, and political aspect of societies. Between these, there are the dynamics of the population growth; the demand of resources by individuals and communities; the technology used to obtain, transform, and transport products; the legal frameworks of the societies; and the management of the rights over the use and enjoyment of benefits generated from the use of the resources (Fig. 2.1).

Erlich and Holdren (1971) and Ehrlich and Ehrlich (1990) propose a general model, known as "IPAT," which is a simple way that tries to integrate the main components that impact the transformation of the ecosystems (I) and that are responsible for the human footprint on the environment. These components are (a) population size (P); (b) consumption that the society demands, also called affluence (A); and (c) the technological and political administrative development (T) with which the society counts to produce the goods and manage their waste. These components are interacting in such a way that the impact caused by the population can be expressed in a general way as:

$$I = P^{*}A^{*}T$$

where I = impact, P = population, A = consumption, and T = technology and administration.

However, this model is a simplification of the complex interactions that occur between the society and the environment and does not explicitly indicate the intrinsic and irreplaceable value of biodiversity and the ecological processes that allow the functioning of the biosphere (Challenger and Dirzo 2009).

2.3.1 Population Growth

Below are some data that allow us to have a panorama of the demographic and socioeconomic problems by which Mexico is going through, in order to visualize the urgency of promoting a sustainable use of Mexico's natural capital.

The territory of Mexico is 1.97 million Km^2 (thirteenth largest country in the world) and has 123.52 million inhabitants, making it the tenth most populated country in the world and the third in America, after Brazil and the United States.

The pressure on the use of resources, in Mexico, is constantly increasing; this is due to a continued population growth that in 2013 was at a rate of 2.29% per year, with about 45% of its population under 25 years of age. In addition, there are other sociocultural factors that accelerate this growth, such as the increasing teenage fertility rate, which is 62.65 per 1000 teenagers.

The spatial distribution of human population in Mexico is very heterogeneous. This is due in large part to inequitable opportunities between cities and country sides. This produces an annual urban growth of 1.6%, while the annual rural growth is −0.02% per year. Between 2000 and 2010, the population of Mexico increased around 15 million, and the localities with the highest increase were the most populated (100,000 and more inhabitants) where 47.8% of the national population is located (INEGI 2013). The biggest socioeconomic problems facing the country are the high percentage of poverty that reaches 49.5% of its population and the educational backwardness that occurs in 19% of the population, situations that are more serious in rural areas and in female sector of the population (CONEVAL 2012).

The transformations of natural environments of the Mexican territory, **began since** pre-Columbian times since we have evidence that diverse cultures settled along this area, but perhaps one of the strongest transformations occurred during the time colony, as new species of plants and animals were imported by Spaniards. At the same time, new technologies and ways of acquiring and using recourses were introduced.

New ecosystem changes arose in the middle of the nineteenth century and early twentieth century, due to the industrialization and electrification of the country. These factors have accelerated the trend toward urbanization, which has led to a reduction of the rural population from 60% (in 1930–1940) to 23.2% in 2010 (localities of less than 2500 inhabitants) (INEGI 2013).

The metropolitan area of Mexico City is the tenth most populated human conglomerate in the world and the second in America, with around 21 million inhabitants (CONAPO 2015). The interactions of a large metropolis such as Mexico City, as well as some other capitals and large cities of the country, become a danger to the environment and human well-being, as they become centers that hoard resources and produce waste and pollutants that affect surrounding areas.

The case of Mexico City, in relation to water, is remarkable. This city is located in the Valley of Mexico at an altitude of 2240 m above sea level and is settled in the sediments of a lake that have been almost dewatered. This city demands a large amount of drinking water. Currently, the water is extracted in part from the groundwater aquifers of the same city, which have already been overexploited, causing settlements by compaction in some parts of the city. However, 25% of the drinking water is brought to the city, from distant regions through the Cutzamala hydraulic system, which began to be built in 1982 and that currently supplies the city with 9000m^3 of water/segundo. This system is a great work of hydraulic engineering and is one of the most important of its kind worldwide. The water is conducted through open channels, tunnels, and aqueducts, along 330 km, and is raised 1100 m from its place of origin in Michoacán, so this journey is very expensive and requires the use of six very potent pumping plants (Conagua 2005).

The water demanded by Mexico City causes problems in the ecosystems and rural populations from where the liquid is extracted. At the same time, the drainage of the sewage produced by the city that unfortunately is mixed with rainwater has required the installation of expensive drainage systems to lead them toward the basin of the Moctezuma and Pánuco rivers through the rivers Cuautitlán and Tula. The Tula River is considered one of the most polluted rivers in Mexico, and yet its waters are retained in several dams (La Requena and Endho) and used for irrigation of agricultural areas in the semiarid valley of the Mezquital (Hidalgo) (Conagua 2005).

2.4 Strategies for Conservation

Given the complex socioeconomic panorama of the country, it is imperative to look for alternatives of sustainable development that guarantee the conservation of the biological heritage, which provides goods and services to the population. It is also imperative that this development achieve "the eradication of poverty, which is the first of the Sustainable Development Goals (SDG), that is a need and a moral imperative for our societies, especially at this time of the history where the world has enough resources to satisfy the basic needs of all the population to reach adequate levels of life" (Barcena 2017).

However, achieving this goal is complex in societies where there is no equality and social justice. This situation is generated by a non-equitable benefit of the enjoyment of the goods and services that ecosystems provide. If we can consider the socio-ecosystems as a unit, it could help us make correct decisions about the use of nature (diversity of species and ecosystems) not only to acquire short-term benefits but also to promote the permanence of goods and services for the welfare of society.

This approach is especially important in a country such as Mexico, where the peasants and many indigenous communities have traditions and a cultural and religious heritage that allows them to make multiple and sustainable use of their resources: cultivation of variety of plants and use of wild and semidomesticated plants as food and medicinal resources and in religious ceremonies and hunting for self-consumption. This relationship model between society and ecosystems differs from the conventional model of economic development that only measures the value of the environment and natural resources in the strictly material and monetary plane (Bye 1993; Casas et al. 1997; Cortés-Calva et al. 2015; Jiménez-Sierra et al. 2017; Lira and Caballero 2002).

The conservation of biological wealth requires an adequate legal support, which is given in Mexico by various laws related to the care of the environment, including the General Law of Ecological Balance and Protection of the Environment, the General Law of Sustainable Fisheries and Aquaculture, the General Law of Sustainable Development, the General Wildlife Law, and the General Law on Climate Change. Likewise, agreements and international programs signed by Mexico such as the Kyoto Protocol (1997), the Nagoya Protocol (2010), and the United Nations Environment Programme (1972) are also decisive. However, on December 2017, a new law was proposed by goberment, although it has not yet been approved, the General Law of Biodiversity, which has been strongly questioned by environmentalists and academics because it allows mining and hydrocarbon exploitation in protected natural areas. This represents a serious danger for the conservation of Mexico's biodiversity, since within NPA, 57,255 ha have been granted for mining projects (Ballinas and Becerril 2017).

The Secretary of the Environment and Natural Resources (Semarnat) and the National Commission of Natural Protected Areas (Conanp) are the principal institutions responsible of the management and conservation of the biological resources. The management of protected natural areas in Mexico should involve the indigenous groups and the rural communities who are the owners of the lands. Villagers must be involved both in the monitoring of biological resources and in the design of strategies for the use of resources. The development of productivity activities, such as ecotourism, should benefit directly the inhabitants of these areas (Semarnat-Conanp n.d.).

Although, efforts made by Mexican government for conservation of natural heritage have undoubtedly been of great importance and in some cases the implemented programs seem to have an incipient success in the rescue of some species at risk as is the case of the Vizcaino pronghorn (Fig. 2.2) or the reintroduction of the Mexican wolf (Fig. 2.3) and the case of the old man cactus (Fig. 2.4), it is necessary to increase these efforts, since at least 2587 species of plants and animals that live in Mexico are threatened (Semarnat 2010).

Natural reserves appear to be a suitable alternative for preservation not only of individual species but of all species that make up the ecosystem. In addition, in these areas, more equitable accessibility to ecosystem goods and services can be promoted (Jiménez-Sierra et al. 2017; Ortega-Rubio 2015). However, the allocation of economic resources for the management of natural protected areas should be increased, since personnel and resources for surveillance are scarce. Beside this, it is necessary to strengthen the system of connectivity between protected natural areas in order to allow migration of populations of plants and animals in the face of the threats of climate change (Torres-Orozco et al. 2015; Jiménez-Sierra et al. 2017).

In 1992, the government of Mexico created the National Commission for the Knowledge and Use of Biodiversity (CONABIO), whose mission is to promote, coordinate, support, and carry out activities aimed at knowledge of biological

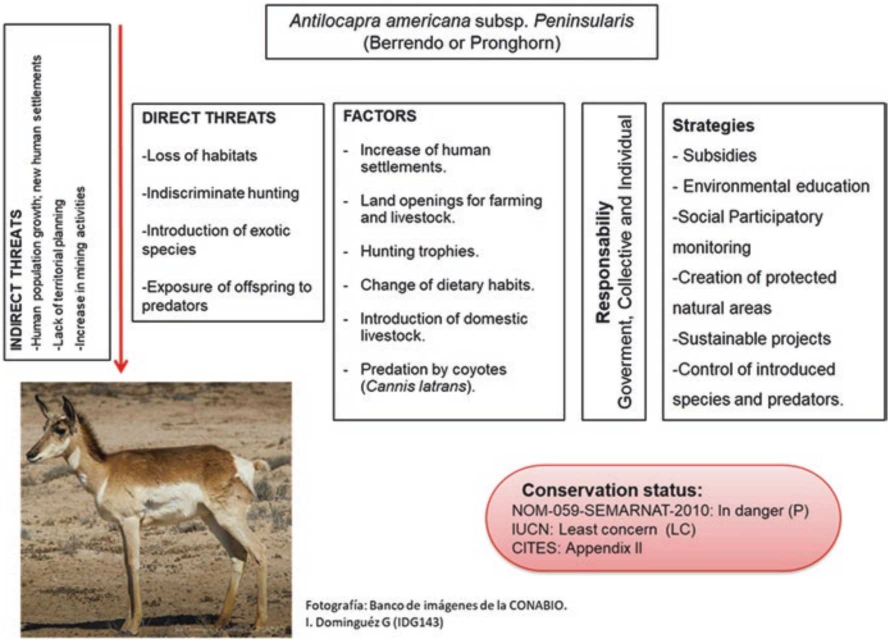

Fig. 2.2 The case of Vizcaíno Pronghorn: an example of success in increasing the number of a population that was close to his disappearance due to hunting and habitat transformation
Historical distribution: a wide region of the peninsula of Baja California (Mexico)
Current distribution: a small area within the El Vizcaíno Biosphere Reserve
Population size: in 1995, the pronghorn population in the area was between 150 and 170; in 1997 only of 17 individuals
Recovery actions: Let's Save the Pronghorn Program, supported by civil society (ejidatarios), National Commission of Natural Protected Areas (CONANP), and private initiative (NGOs). In 1996 some specimens bred in captivity were introduced
Results: the program seems to have been successful, since, in 2017, the pronghorn population had increased to 500 (Cancino 2005; Cruz 2015; Goldman 1945)

diversity, as well as its conservation and sustainable use for the benefit of society. It was conceived as an applied research organization and promoter of basic research, which compiles and generates information on biodiversity, develops human capacities in the area of biodiversity informatics, and is a public source of information and knowledge accessible to the whole society (Conabio 2017).

Today there are various nongovernmental programs that support the conservation of natural environments, such as the programs of Payments for Ecosystems Services (PES) and Programs of Carbon and Forestry Bonds, and some private and governmental programs like PROCAMPO and PROCODES.

In order to prevent species extinction due to overexploitation, the government has promoted programs like Environmental Management Units (UMA) (Robles 2009), Veda programs, Action Programs for Species Conservation (PACE), Projects for Recovery and Conservation of Priority Species (PREP), and Conservation Programs for Species at Risk (PROCER) (Semarnat 2014).

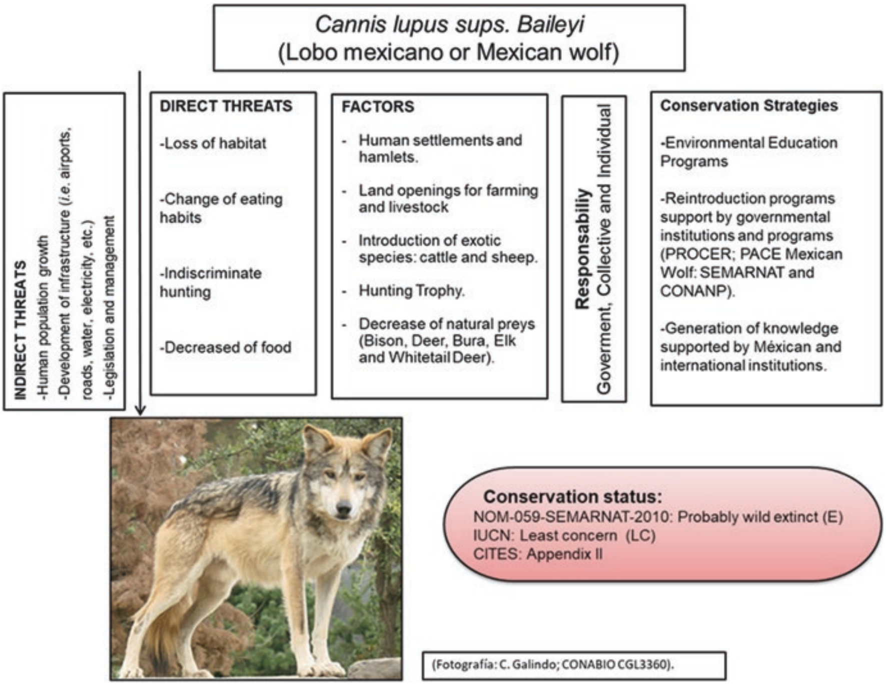

Fig. 2.3 The Mexican wolf, *Canis lupus* subsp. *baileyi* is an example of a species which practically disappeared from its natural habitat and for which the government and biologists are fighting to reintroduce it to their natural habitat from captive-bred individuals
Historical distribution: from the Southwestern United States to southern Mexico (Oaxaca)
Current distribution: practically extinct in its natural habitat. Causes of its disappearance: decrease of its natural prey and introduction of sheep and cattle. Direct hunting of specimens because they are considered predators of livestock and rabies disseminators
Recovery actions: since 2011, individuals that bred in captivity have been introduced into natural habitats in Sonora and Chihuahua
Results: currently it is estimated that the wild population is 31 individuals; however, the genetic variability they possess is very low because all the organisms come from a low number of specimens kept in captivity (Malpica 2017; Romeu 1997; Semarnat-Conanp 2009)

Regarding the problem of invasive species, attempts are made to list invasive species and manage their early eradication (Aguirre et al. 2009). Faced with the pollution problem, standards are established, and incentives are created to reduce industrial waste. To mitigate climate change, programs are developed to generate and use clean energy (INECC 2014).

However, no action will be sufficient if society have not enough awareness about of the consequences of personal and collective actions on the environment, since the conservation of biodiversity is the responsibility of each and every one of the members of society.

Environmental education is essential to raise awareness about the relationship that conservation has on personal well-being. Through it, a new culture and ethical

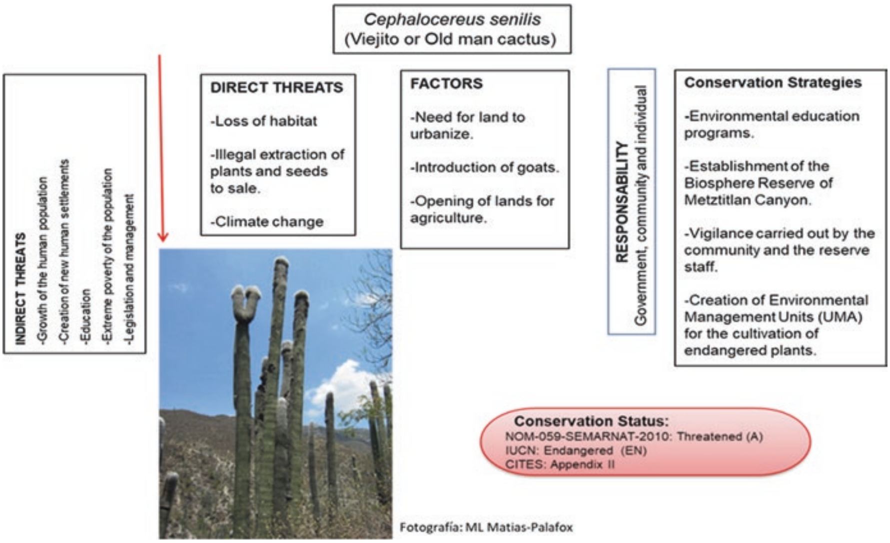

Fig. 2.4 The "Old Man Cactus" (*Cephalocereus senilis* Haw. Pfeiff., 1838): example of an endemic species at risk that now is protected by the inhabitants, thanks to the programs supported by the Biosphere Reserve of Metztitlan Canyon
Historic distribution: endemic to Metztitlan Canyon (Hidalgo and Veracruz State) (Bravo-Hollis and Sánchez-Mejorada 1991)
Current distribution: some populations have disappeared or are affected by lands opening to agricultural or to the establishment of settlements
Causes of population decline: modification of the environment. Introduction of goats. Looting of seeds and individuals by national and foreign amateurs. The species is very vulnerable due to its low recruitment rate as for the slow individual growth rate
Conservation strategies: establishment of the Biosphere Reserve of Metztitlán Canyon in 2000. Implementation of a monitoring system. Environmental education workshops. Now, residents appreciate and protect their natural resources. The establishment of Management Units for the Conservation of Wildlife (UMA) in 2004 has allowed to cultivate "viejitos" given to the villagers with the possibility to obtain economic benefits, and at the same time, the illicit extraction of specimens from wild populations has been stopped (CONANP 2003; Jiménez-Sierra and Matias-Palafox 2015; Jiménez-Sierra et al. 2017)

attitudes toward nature can be achieved. Society must be well informed about the impact that the production and consumption of goods has on the environment. Knowledge of our ecological footprint can change attitudes toward nature (Fig. 2.1).

2.5 Conclusions

Biodiversity of Mexico is at risk due to perturbations that man has made on natural environments.

To mitigate *the effects of the direct threats*, some concrete actions have been developed. However, the *indirect threats* are overlooked. Between these last, it is important to consider *human population growth*, because this population will require the transformation of more habitats to cover food and housing needs. Furthermore, *the lack of justice* in the distribution of the goods and services that the ecosystems provide causes great differences in the development opportunities between the countryside and the cities. Rural people migrate to the cities leaving their land, and this causes the loss of traditional knowledge about the use of local resources. In addition, the increase of technified monocultures leads to a greater disturbance and loss of ecosystems.

Loss of natural environments threatens the persistence of many species. Also since efforts to save an endangered species are costly and uncertain, the most sensitive thing is *to conserve the functionality of the ecosystems*. Then, the performance of isolated actions to avoid the loss of one species is not enough. It will be necessary to consider the *socio-ecosystems* (inhabitants and environment) as a unit to develop strategies that allow the social and economic development of the inhabitants conserving the ecosystems of which they are and will be the beneficiaries.

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Chapter 3
Patrimonialism, Natural Resource Management, and Civil Service in Mexico: Lessons Learnt from the Last 30 Years

Alfonso Aguirre-Muñoz

Abstract As the incipient Mexican democracy unfolds, governance and institutional challenges emerge accordingly to attend with efficacy the subjects posted by the unparalleled current environmental crisis. A crucial part is the creation and adaptation of institutions that have as mandate to answer to the complex environmental conjuncture. However, the institutionalization process is still struggling to achieve a strong foundation, particularly the federal government that plays a decisive role in that regard. To better understand the dynamics of public management and policies with respect to environmental conservation and natural resource governance in Mexico, a detailed examination of the public service officers' trajectories during the last three decades is presented, advancing an original analysis—including an index—to characterize the institutional arrangements and recognize the factors driving it. The results add elements for a reflection on Mexican governance, ideally, to improve the development of environmental institutions and its tangible results.

Keywords Environment · Patrimonialism · Governance · Civil service · Mexico

3.1 Introduction: Mexico in Crisis

Mexico is in the middle of a complex and difficult historic conjuncture. Social, economic, political, environmental, and human rights factors reveal the worst multicausal crisis ever faced by the country since the Mexican revolution, already one century ago. By and large it is a situation that has been described as the "Mexican dystopia" (Meyer 2016), referring to the most extreme opposite perspective to the ideal of a utopian vision or to a positive and viable project for the nation's future.

Corruption as a symptom of general social distress, instead of being controlled, has been growing up rampantly to achieve nowadays very concerning levels. The international Corruption Perceptions Index (CPI) shows that Mexico fell down in

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A. Ortega-Rubio (ed.), *Mexican Natural Resources Management and Biodiversity Conservation*, https://doi.org/10.1007/978-3-319-90584-6_3

2017 to the position 135 of the 180 evaluated countries from all over the world in regard to anticorruption measurements (Transparency International 2018). In this ranking the country went down to achieve in 2017 only 29 points in a scale from 0 (worst) to 100 (best). As well, corruption-wise Mexico was the worst evaluated country from the 35 OECD countries. Consistently, from 2012 to 2017—the present presidential term from Enrique Peña Nieto of the official PRI party—Mexico went down in the CPI from place 105 to the present 135. Accordingly, the World Economic Forum (WEF), in its annual corruption index as part of its *Global Competitiveness Report* (WEF 2016), ranked Mexico as the 13th most corrupt country in the world, and the most corrupt one if the less-developed countries are excluded, recognizing that the incessant increase of organized crime was decisive for Mexico having obtained such a negative rank. Likewise, Mexican federal government official statistics show that Mexicans consider corruption as the second most important matter that the country faces, second only to insecurity: 88.8% of the population considered that corruption is a practice that occurs frequently or very frequently among government officers and employees, being perceived as an abuse in their legal mandates to obtain personal benefits (INEGI 2017).

At the same time, the lack of effective governance has originated rampant violence. A detailed and consolidated crime time series from 1926 to 2008 shows that there is an exponential growth in crime rates that starts to unfold in 1980 with 180 crimes per 100,000 inhabitants (Piccato and Lajous 2018). The crime rate growth keeps on going until today arriving to a very critical level. The homicide index per 100,000 inhabitants in 2017 as compared to 2011—year with the already largest historic rate of homicides—had an additional increase of 5.09%, arriving Mexico to a new historic record and showing the level of disintegration of social relations and lack of accountability by government agencies (Observatorio Nacional Ciudadano Seguridad, Justicia y Legalidad 2018).

As an underlying cause of corruption and the collapse of social cohesiveness, inequality is an essential social and political trouble in Mexico. Meyer (op. cit.) establishes that subordinating power to equality and social justice is still a fundamental pending task: When Mexico had the chance to move into that direction, thanks to the political change decided by the popular vote in the presidential election of 2000—Vicente Fox, from the opposition's right wing catholic PAN party won the elections—the power elite impeded it, resulting in the return of the PRI official party in 2012 and in a massive collective frustration. Mexican inequality—as established by the Gini Index—is the second worst of the OECD countries and is not being positively impacted by government redistributive intervention. The 2017 Gini Index in Mexico is 0.46 before collecting taxes and 0.45 after collecting taxes. In Germany the Gini Index thoroughly improves from 0.50 before taxes to 0.27 thanks to the redistributive government intervention (Raúl Livas, in Aguilar Camín 2018).

Negative scenarios are also true for the state of the country in regard to environmental resources and conservation. Contrary to the self-approval thought that "the actual federal government is the most environmentalist one in Mexican history," as stated recently by the Secretary of Environment and Natural Resources, Rafael Pacchiano Alamán (Notimex 2018), official data show that the country is facing a severe environmental crisis. Mexico ranked fifth worldwide in deforestation in 2000, with an annual loss rate of 600,000 ha (Mas et al. 2004). More recently, in the period that goes from 2003 to 2013, Mexican forests existence kept on diminishing at a mean annual rate of 0.37% (INEGI 2013). Water pollution measured as the volume of untreated raw sewage discharges had an enormous increase from 8689.5 million cubic meters in 2003 to 21,078.0 million cubic meters in 2013, a 143% total increase for the period, or a 9.27% mean annual growth, also according to official statistics (INEGI, op. cit.). The same federal government official statistics show that the total economic costs due to environmental depletion and degradation between 2003 and 2013 (more recent evaluation) have increased in 39.4%, while the IGP for the same period growth was 109.0%, demonstrating that there is a severe disjuncture—a ratio of 2.8:1—between economic growth and the national cost to prevent and remediate the environmental damage caused by the production and consumption of economic goods (INEGI, op. cit.).

3.2 Patrimonialism and the Case of Mexico

Not denying but accepting that there is indeed a severe environmental and governance crisis in Mexico is an indispensable starting point to move forward and overcome the current profound crisis. Assuming that a functional democracy is the essential element of the nation's desired future—as stated by the Mexican Constitution and existing legal frameworks—the next logical steps for a social and political breakthrough would be to analyze with detail the causes of the impediments to date, look for the corresponding solutions, and honestly and congruently implement them.

Particularly during the last century, Mexico has been resisting to accelerate the pace and move thoroughly into the new times to finally become a modern and real democracy. Historic reasons are among the main explanations. Patrimonialism, as a political organization that came from Spain to the New Spain—later Mexico—with the colonial period and became cultural and deeply rooted in the country, is a component of such resistance. In patrimonialism legitimate domination and authority are based on the extensive power exercised personally by a ruler. During the foundations of sociology, in the beginning of the twentieth century, Max Weber, a German social scientist, made a comprehensive and historic analysis of forms of domination in the most diverse societies, periods, and geographies. Weber's varied studies became the comprehensive book *Economy and Society* (Weber 1922), printed as a posthumous edition done by his widow Marianne Weber von Fallenstein. In front of the real complex and heterogeneous social facts, as one of the most relevant and original contributions to the methodological basis of comprehensive sociology, Weber proposes as a key analytical tool the construction of "ideal-types" (Idealtypus in German) or pure types—mental concepts or abstract constructs—as instruments that will be confronted vis-à-vis to concrete and historic social situations, analyzing the deviations. That way a basis for the corresponding interpretation and meaning is offered.

Patrimonialism is recognized as a traditional political organization that still has a very conspicuous presence in contemporary Mexico (Meyer 2016; Paz 1979; Zabludovsky 1991). Patrimonialism corresponds to one of the traditional forms or ideal-types of legitimate dominance identified by Weber (op. cit.), e.g., the domination of traditional character, that "rests in the everyday life's believe of traditions that have been reigning since ancient times, and in the legitimacy of the chosen ones by that tradition to exercise authority, the traditional authority." Historically, patrimonialism results of the evolution from a more primitive patriarchal society to reign over a larger geography, linked to the development of agricultural civilizations. In its pure form, authority in patrimonialism is exercised directly by the ruler with the support of a group of members closely related to the ruler—extended family—discretionally controlling each and every feature of governance. It is also characterized by being an unchallenged authority with no power checks and the absence of a recognized rule of law, the ruler responsible only to God and natural law. Such power structure offering no means of rational dissent when in conflict tends to be unstable and presents revolts as the only means of opposition. As well, absence of a rational-legal rule of law and specialized impersonal and paid bureaucracy acts as a barrier for the construction of a modern democracy.

In the case of Mexico, Morse (1964) as a social scientist and historian starts a sound interpretation of contemporary Mexico as having strong historic elements of a patrimonial state, explicitly relating his analysis and categories to Weber (op. cit.). He connects this to the political dominance and heritage of Spain in Spanish America during the colonial times: patrimonialism as a political and cultural heritage. Going to the foundation of patrimonialism in Mexico, he quotes Góngora (1951): "Neither the conquests nor the colonization are private enterprises, undertaken at the margin of the Castillian state." He notes that by then, the public and private spheres were undefined in Spain and still in the process of separation. Grants of soils and mines were exclusively royal concessions in the New Spain, not ruled by private law. This marked the development of the New Spain with a conservative influence that characterized Spain and Portugal—related to seven centuries of Moors presence—resulting in a "neo-medievalism." Meanwhile in the rest of Europe, changes toward modernity that led to the "statist" state, the mercantilism, the bourgeois free-enterprise state, or the "imperialist" state were already taking place. The conclusion of Morse is precisely that because the Spanish Indies were part of a universal Christendom, then they were not real colonies, nor was the Spanish expansion a conquest "insofar as this means the acquisition of alien lands and peoples." Therefore the Spanish Indies "were incorporated into Christendom, directly under the Spanish crown, by a specially designed and carefully legitimized patrimonial state apparatus." Furthermore, Morse proposes that: "These principles of society and government help us not only to understand Spanish rule in America, but also to assess the impact of the Enlightenment on Spanish America, to analyze the process by which the Spanish American nations became independent, and to interpret their subsequent political careers." And finally: "If we accept seriously the notion that Spanish

America had taken a cultural and institutional fix long before this time, we are interested in identifying a deep-lying matrix of thought and attitude, nor the rhetoric by which it may for the moment have been veiled." Morse, with this analysis and recognizing as well the influence of the Thomist theory, sets the matrix "to cast the model of the patrimonial state in terms that allows us to trace it persistence unequivocally in modern Spanish America."

From Weber's description of the ideal-type patrimonialism, and already associated to our concern in regard to a professional civil service, Morse (op. cit.) summarizes the following characterization, strongly reflecting the Latin American countries political and social structures:

- The patrimonial ruler is ever alert to forestall the growth of an independent landed aristocracy enjoying inherited privileges. He awards benefits, or prebends, as a remuneration for services.
- Income accruing from benefices is an attribute of the office, not of the incumbent person.
- Characteristic ways for maintaining the ruler's authority intact are limiting the tenure of royal officials, forbidding officials to acquire family and economic ties on their jurisdictions, and using inspectors and spies to supervise all levels of administration.
- The authority of the ruler allows him to claim full personal power; reluctant to bind himself by law, his rule takes the form of directives, each subject to supersession.
- The administrative and judicial functions are united in many different offices.
- Legal remedies are not applications of law, but gifts of grace or a privilege awarded on the merits of the case and not binding as precedent.

Octavio Paz (op. cit.) aligned with Weber's and Morse's characterization of a patrimonial state to describe contemporary Mexico—in opposition to a truly modern state and well beyond the colonial times—sees how the Mexican state exhibits a strong contradiction. In a paradoxical way, pretending to be the agency for modernization, the state itself has been the barrier for the purpose, he notes. The historic context Paz refers to is the end of the twentieth century, particularly to the year 1978 (date of the original publication), and his description remains valid to date:

> The government staff and employees, from the ministers to the clerks and from the judges and senators to the doormen, far from constituting an impersonal bureaucracy, it forms a great political family linked by kin relationships, friendship (…) and other personal factors. Patrimonialism is private life embedded in public life. The ministers are relatives and servants of the king. In the patrimonial regime what if counts at the end is the will of the Prince and their closest ones (…). This courtesan society is partially renewed every six years, that is every time the new president takes hold of power. Because of its situation and its implicit ideology and the way they are recruited, this courtesan bodies are not modern: they are a survival of patrimonialism. The contradiction between a courtesan society and a technocratic bureaucracy does not immobilize the State but it makes its march indeed difficult and sinuous. There are not two policies within the State: There are two ways of understanding politics, two types of sensibilities and moral.

The way out—this medieval inheritance seen as a serious barrier to achieve a modern democracy in Mexico—is, according to Paz, "the dismantlement once and for all of the government patrimonialism and convert Mexico into a real modern society and State. "Modernization" can be defined in a concise and essential way as an initiative to return to society what was taken away from it, and break that way the forced immobilization that State patrimonialism has condemned us to."

Zabludovsky (op. cit) notes how the criticism against patrimonialism was adopted by the official ruling class in a cynical way. Disregarding the reflection and the implications about their own patrimonial ideology as government officers, they turned the negative connotation to the "leftovers of the old regime," such as the unions and the welfare state, setting aside all the possible implications that would relate to the executive power. This typical kind of accommodating double discourse generates confusions and somehow delays social change as Sefchovich (2008) observes, involving the intentional and whole creation of a fake country with an enormous distance between the discourse by the power elite and the nation's factual reality, "The Country of Lies," or "*El País de Mentiras*" in Spanish.

It is with this preamble that I will now analyze in a detailed way the professionalism level of the high-rank federal government officers who have had the responsibility of taking decisions in regard to the country's environmental issues during the last 30 years.

3.3 Professional Ideal-Type and the Absence of Civil Service in the Environmental Sector

The ideal-type methodology from Weber (op. cit.) is very useful for social analysis, not only because of the general categories he constructs correspondingly, for instance, to domination types, as patrimonialism. In the following analysis, at a much more analytical and detailed level, I use as general framework the same Weberian perspective, now in regard to the existence of the ideal-type of a rational state whose structure and functions are based in its pure form on its anticipated ability to achieve an explicit end. In our approach explicit and rational end is the sustainable management of the country's natural resources—as a process—to achieve social and economic benefit for the Mexican people and the conservation of Mexico's nature, as a product. Such a rationality oriented toward ends on public issues clearly diverges from patrimonialism and even confronts it directly, i.e., they are not compatible as modern government ideologies.

To conduct the detailed analysis, I propose as a working hypothesis that the ideal-type professional officer to run the environmental government agencies should possess a consistent and congruent trajectory. Such ideal trajectory is defined by the professional formation and working experience that effectively offer a complete fit with the profiles and eventually should facilitate the good exercise of the mandate, for instance, as Secretary of the Environment and Natural Resources, the highest responsibility within the Mexican federal government structure.

For the purpose, here I advance the construction of an original and ad hoc ideal-type—a model or conceptual abstraction—to be used as a reference, allowing us to make a numerical and graphic analysis of how well an officer fits the job's requirements or profile. Graphically it is represented by an instant image of a star with five arms, capturing five periods of a biography. As a clock's dial with the arms moving clockwise from the top (the profession, as the North of a compass) to the right (the working experiences), the image crystallizes such five periods related to the professional trajectory: (1) professional formation, (2) second job previous to the analyzed position, (3) first job or immediately previous to the analyzed position, (4) first subsequent job after the analyzed position, and (5) second subsequent job after the analyzed position (Fig. 3.1).

Each period has a value of 0–3 points. In the concrete cases, it will vary according to how proper the actual and measured fit results. So, the ideal-type in its pure condition adds a maximum total of 15 points when considering the optimal evaluation for all the five periods. The 15-point scale—from a minimum of 0 point to a maximum of 15 points—gives the content to a professionalization index (PI), an original proposal from this study. The PI is afterward numerically transformed to a scale from 0 to 1. The graphic representation of the star, when showing the perfect pentaradial symmetry—with the longest possible arms for each period—demonstrates maximum congruency or fit between the job's professional requirements and the needed experience and also the consistency of a lifetime professional trajectory (Fig. 3.1). The total sum of the perfect star would be 15 points, and the corresponding PI would be 1.

The professionalization evaluation is conducted for Mexico's federal government to the high-rank and responsible officers of the following agencies:

1. The Secretariat of Environment and Natural Resources or SEMARNAT (that evolved from the former Secretariat of Environment and Natural Resources and Fisheries or SEMARNAP and the Secretariat of Fisheries or SEPESCA), since the creation of the original office, in 1976, and until today (Tables 3.1 and 3.2, Fig. 3.2)

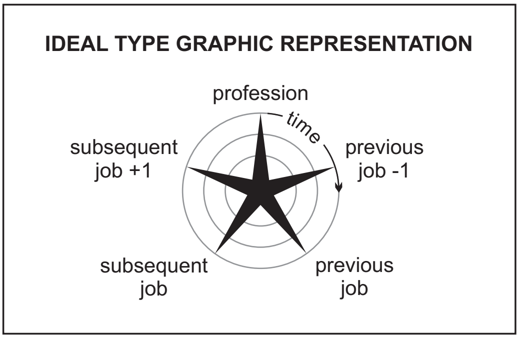

Fig. 3.1 Ideal-type graphic representation of a government officer

2. The National Commission of Natural Protected Areas or CONANP since the creation of the original agency, in 1994, and until today (Tables 3.3 and 3.4, Fig. 3.3)
3. The National Commission of Fisheries and Aquaculture or CONAPESCA (that evolved from SEMARNAP and SEPESCA) since the creation of the office in 1976 (Tables 3.5 and 3.6, Fig. 3.4)

To frame Mexico's analysis in a wider context, the professionalization evaluation is also applied to a group of environmental agencies from diverse countries: Argentina, Brazil, Canada, Chile, Colombia, France, Germany, and USA (Tables 3.7 and 3.8, Figs. 3.5 and 3.6). As well, the evaluation is performed to a group of Mexican civil society organizations (NGO) specialized in environmental conservation, particularly in Mexico's northwest region, where conservation is an important social construction (Table 3.9, Fig. 3.8).

The information about the professional trajectories from the government officers from Mexico and elsewhere came from official public biographies and newspaper articles. As for the NGO's executive directors, the information to feed the evaluation came from direct personal contacts. The biographical notes for the evaluation are summarized in tables, by each group, first as text, and then quantitatively traduced into the corresponding numeric values. The most aggregated results are presented as the graphs of stars with five arms.

To illustrate the condensed biographical information presented in the tables, I summarize here two contrasting biographies. Guillermo Jiménez Morales, from the PRI official party, was the head of the federal Secretariat of Fisheries or SEPESCA—the origin of SEMARNAT and CONAPESCA—from 1991 to 1994. His professional formation was as a lawyer. Before being appointed by President Carlos Salinas de Gortari as Secretary of Fisheries, he was a congressman, and before that he was governor of the State of Puebla. After leaving the Secretariat of Fisheries, he was appointed Ambassador to the Vatican State; later he was appointed as Undersecretary of Religious Matters from the federal Secretariat of Governance. The fit with the post is very low.

Contrariwise, Julia Carabias Lillo was appointed by President Ernesto Zedillo Ponce de León as Secretary of the Environment, Natural Resources, and Fisheries (SEMARNAP) from 1994 to 2000, occupying the post during the full 6-year presidential term. She studied biology at the National University (UNAM) completing as well a graduate course in ecology. Before that she was President of the National Institute of Ecology (INE) and researcher in applied ecology at UNAM. After leaving the secretary of state responsibility, Carabias Lillo returned to the university and collaborates in conservation and sustainable development projects in the jungle of Southeast Mexico. Carabias' fit with the profile is optimal, fully corresponding to the reference ideal-type (Tables 3.1 and 3.2 and Fig. 3.2).

The analysis of the personal trajectories of the SEMARNAT secretaries of state—the country's highest responsibility in regard to decisions and governance affecting the environmental quality of 120 millions of Mexicans—shows extreme differences between the highest-ranked officers, Julia Carabias, obtaining the maximum assessment of 15 points or a professionalization index (PI) of 1, and the lower

Table 3.1 Trajectories of Secretaries of Environment and Natural Resources SEMARNAT (before SEMARNAP and SEPESCA) from 1976 to 2018

Name	Period	Profession	Previous job (−1)	Previous job	Subsequent job	Subsequent job (+1)
Fernando Rafful Miguel	1976–1982	Economist	Undersecretary of National Patrimony	Senator by the state of Campeche	Advisor to the Secretary of Fisheries	Government Secretary from the state of Campeche
Pedro Ojeda Paullada	1982–1988	Lawyer	President of the PRI party	Secretary of Work	President of the National Commission of Food	President of the Mexican Geography Society
María de los Ángeles Moreno Uriegas	1988–1991	Economist	Undersecretary of Social and Rural Development from the Secretary of Budget	Undersecretary of Social and Regional Development from the Secretary of Budget	Federal Congressman	Secretary and President of the PRI party
Guillermo Jiménez Morales	1991–1994	Lawyer	Governor of the state of Puebla	Federal Congressman	Ambassador to the Vatican State	Undersecretary of Religious Matters
Julia Carabias Lillo	1994–2000	Biology with postgraduate course in Ecology	Ecology Researcher UNAM	President of the National Institute of Ecology	Ecology Researcher UNAM	Ecology Researcher UNAM and conservation projects
Víctor Lichtinger Waisman	2000–2003	Economist with postgraduate course	Director Manager of the Trilateral Environmental Commission	Advisor to the Central America Commission for Environment and Development	Consultant	Staff Coordinator for Planning—Government of the State of Michoacán
Alberto Cárdenas Jiménez	2003–2005	Industrial Engineering with postgraduate courses	Governor of the state of Jalisco	Director General of the Forestry Commission CONAFOR	Senator PAN	Senator PAN

(continued)

Table 3.1 (continued)

José Luis Luege Tamargo	2005–2006	Chemical engineering and postgraduate course	President of the PAN Party in Mexico City	Environmental Federal Prosecutor PROFEPA	Director General of the Water Commission CONAGUA	Director General of the NGO Ciudad Posible, devoted to urban development
Juan Rafael Elvira Quesada	2006–2012	Agriculture engineering with postgraduate course	Director General of Primary Sector SEMARNAT	Undersecretary of Environmental Norms SEMARNAT	Consultant	Consultant
José Juan Guerra Abud	2012–2015	Industrial engineering with postgraduate course	President of the National Association of Buses and Truck Producers (ANPACT)	Federal Congressman by the Green Party PVEM	Ambassador to Italy	
Rafael Pacchiano Alamán	2015–	Industrial engineering	Federal Congressman by the Green Party PVEM	Undersecretary of Environmental Protection SEMARNAT		

Table 3.2 Evaluation of the trajectories of Secretaries of Environment and Natural Resources SEMARNAT (before SEMARNAP and SEPESCA) from 1976 to 2018

Name	Period	Profession	Previous job (−1)	Previous job	Subsequent job	Subsequent job (+1)	Total	PI
Fernando Rafful Miguel	1976–1982	2	2	1	3	1	9	0.60
Pedro Ojeda Paullada	1982–1988	1	0	1	2	1	5	0.33
María de los Ángeles Moreno Uriegas	1988–1991	2	2	2	1	0	7	0.47
Guillermo Jiménez Morales	1991–1994	1	0	1	0	0	2	0.13
Julia Carabias Lillo	1994–2000	3	3	3	3	3	15	1.00
Víctor Lichtinger Waisman	2000–2003	2	1	1	1	0	5	0.33
Alberto Cárdenas Jiménez	2003–2005	0	0	1	1	1	3	0.20
José Luis Luege Tamargo	2005–2006	0	0	2	1	0	3	0.20
Juan Rafael Elvira Quesada	2006–2012	2	3	3	1	1	10	0.67
José Juan Guerra Abud	2012–2015	0	0	1	0	0	1	0.07
Rafael Pacchiano Alamán	2015–2018	0	1	2	0	0	3	0.20

ones. The lowest-ranked ones, showing a huge deficit in formation and experience, are the two SEMARNAT secretaries that have had the responsibility during the ongoing 6-year term of President Enrique Peña Nieto, from the PRI official party, and two of the former presidential term of President Felipe Calderón Hinojosa, from the PAN party: José Luis Luege Tamargo and Alberto Cárdenas Jiménez.

Juan José Guerra Abud and Rafael Pacchiano Alamán, the two secretaries running the office during the current regime, are both from the Mexican green party Partido Verde Ecologista de México (PVEM). The green party was part of a winning electoral alliance with the PRI for the current presidential term. Juan José Guerra Abud—an engineer with experience in the automotive industry—gets the lowest PI score: 0.07. When Guerra Abud was Secretary of Economic Development of the State of Mexico, President Peña Nieto was his personal assistant. In the middle of

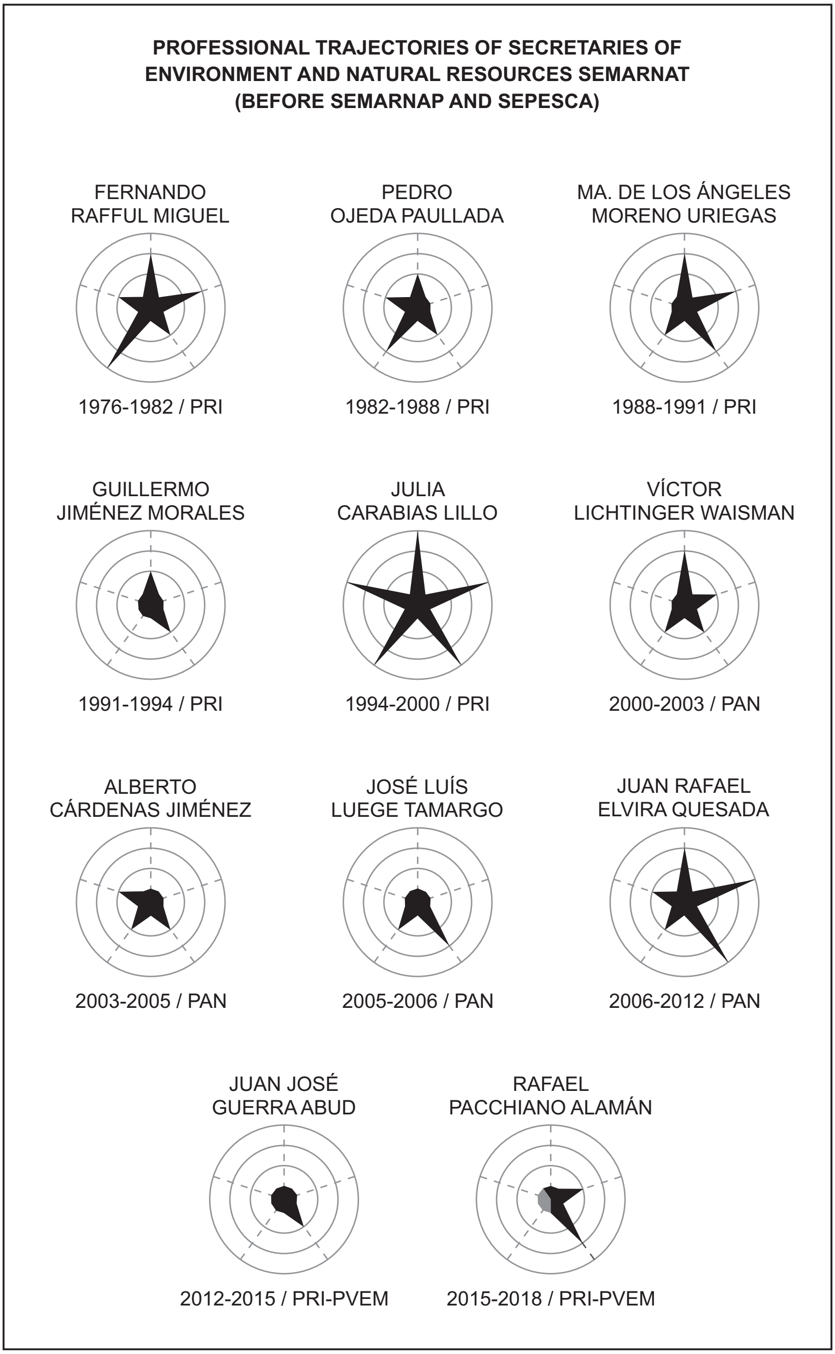

Fig. 3.2 Professional trajectories of Secretaries of Environment and Natural Resources (SEMARNAT before SEMARNAP and SEPESCA)

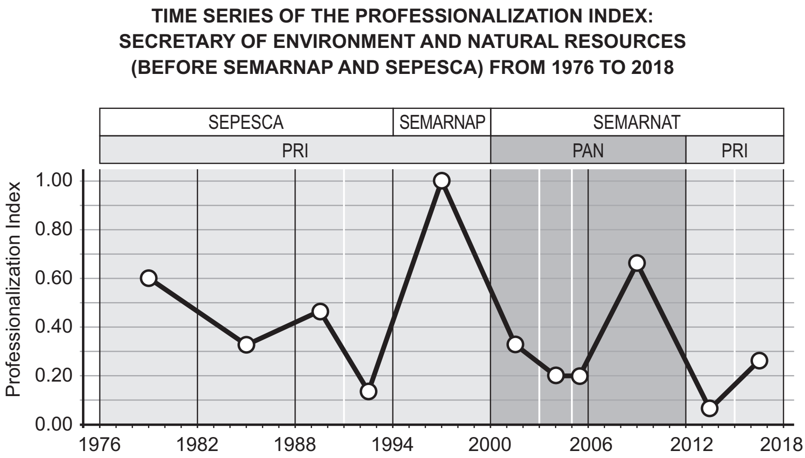

Fig. 3.3 Time series of the professionalization index: SEMARNAT (Before SEMARNAP and SEPESCA) from 1976 to 2018

the current presidential term, Guerra Abud—lacking diplomatic experience—left SEMARNAT in the hands of Pacchiano Alamán, to be appointed Ambassador to Italy. Pacchiano's previous professional experience, with a formation in business administration, was in automobile marketing.

In the long term, a time series of the PI from 1976 to 2018 reveals that the secretaries' formation and experience to run the office are totally independent of the party in power (Fig. 3.3) and that the average is far from the ideal-type of a rational state oriented to the public good in the terms of Weber (op. cit.). PRI governments have the best ever secretary—Julia Carabias Lillo—and the least prepared one: Juan José Guerra Abud. It is clear that the decision of the president to appoint for the job one or another officer as his secretaries of state is fully discretionary, even though governing environmental issues demand a high level of specialization. In the case of President Zedillo Ponce de León, he resolved in 1994 to appoint Carabias Lillo as secretary, a professional with the ideal formation and experience to both design the structure of the office and run it for the whole presidential period. It is interesting to note that José Woldenberg—a respected academician—by then the husband of Carabias was a citizen member of the Federal Electoral Institute (IFE) that qualified Zedillo's election. On the other hand, belonging to the same political coalition PRI-PVEM, President Peña Nieto appointed as secretaries Guerra Abud, his former boss, and Pacchiano Alamán, the husband of Alejandra Lagunes Soto Ruiz, Coordinator of Digital Strategy (social media) of Peña Nieto President's office.

Similarly, President Calderón Hinojosa appointed during his year term two secretaries that get very low PIs (Alberto Cárdenas Jiménez and José Luis Luege Tamargo) and one with a with a medium to high one (Juan Rafael Elvira Quesada).

Also important to notice is the turnover of the SEMARNAT's secretaries. While with President Zedillo only one secretary ran the office, with President Calderón, SEMARNAT had three secretaries, and President Peña appointed two secretaries. Beyond the eventual low qualifications of the secretaries, a high turnover implies also additional complications for governance. There is a cascade of negative consequences because many close collaborators of the secretary and other employees leave the office as well and also because of losing any experience gained not only by the secretary but also by the ones leaving the office. The accumulation of experience never becomes an asset.

Overall, the time series of Fig. 3.3 also exposes that with time there is a negative trend in the PI. The PI peak with the highest score fully equivalent with the ideal-type was obtained with the PRI and Julia Carabias already 24 years ago. Instead of having a positive evolution, the professionalization goes down to dramatic levels of incompetence, getting to almost 0 with Guerra Abud during President Peña's current presidency.

In the case of the heads of the National Commissioners of Natural Protected Areas CONANP (Table 3.3), the situation used to be very different than the one of the secretaries. The qualifications of the CONANP's heads were to a very large extent much higher than the ones of the secretaries with the exception of Julia Carabias, an absolute outlier. The credentials and experience of the first three national commissioners of the National Commission of Natural Protected Areas, dependent from SEMARNAT, were all maximum or close to maximum. De la Maza, Enkerlin, and Fueyo—in charge of CONANP from 1994 to 2015 and under two different parties—had all strong formation in sciences and valuable previous experience to run the office. De la Maza and Enkerlin get a PI of 1, and Fueyo's PI is also close to the maximum: 0.93. However, in 2015, President Peña Nieto decided to appoint his cousin Alejandro Del Mazo Maza as the new head of CONANP. Formed as a business manager with a limited previous working experience in real estate business and stock exchange, Del Mazo Maza takes the professionalization index to a historic low record of 0.27 (Table 3.4 and Fig. 3.4).

In the long term, during the 24 years of its existence as a national commission, CONANP had a very uncommon low turnover, looking as civil service had arrived to stay at the institution even without a formal and legally binding implementation in that regard. Two of the CONANP's heads—Enkerlin and Fueyo—exceptionally transcended presidential terms, and one of them, Fueyo, even transcended presidential terms from two different parties (PRI and PAN), two extraordinary situations in Mexico's government practices. The conservation community and citizens involved with the protection of nature were already acquainted with commissioners that really knew about the subject. However, the reality check came with the very disruptive appointment of Del Mazo in 2015, collapsing the professionalization index to its minimum with a score close to 0 (Fig. 3.5).

The situation of the public management of fisheries through CONAPESCA closely resembles the one of SEMARNAT. The capacities of the office's heads have varied widely, and overall they are poor (Table 3.5). Aside Julia Carabias, a positive case discussed before, the exception is in the case of fisheries Jerónimo Ramos, an economist that gained experience within the office, starting with limited responsibilities and expertise that later grew and unfolded until being appointed at the national commissioner level. Ramos' trajectory within CONAPESCA also transcended presidential terms and parties. After Ramos two CONAPESCA commissioners with no credentials—Corral and Aguilar—were appointed by the presidents in turn (PAN and PRI), the two of them with PIs scores close to 0 (Table 3.6, Figs. 3.6 and 3.7).

Table 3.3 Trajectories of National Commissioners of Natural Protected Areas CONANP from 1994 to 2018

Name	Period	Profession	Previous job (−1)	Previous job	Subsequent job	Subsequent job (+1)
Javier de la Maza Elvira	1994–2000	Biologist	Director General of Natural Protected Areas System, SEDUE	Director General of Natural Protected Areas System, SEMARNAT	Conservation Project Manager Selva Lacandona	Conservation Project Manager Selva Lacandona
Ernesto Enkerlin Hoeflich	2001–2010	Agricultural Engineer and Wildlife (PhD)	Researcher Conservation ITESM and World Commission of NPA	Director General Pronatura Noreste	Researcher Conservation ITESM	Researcher Conservation ITESM and President of the World Commission of Natural Protected Areas
Luis Fueyo Mac Donald	2011–2015	Phycist, Hydroacoustics (MSc), Coastal Lagoons	Director General, Inspection of Marine Resources and Coastal Ecosystems, PROFEPA	Advisor to the Executive Secretary of CONABIO	Environmental Consultant	Natural Resources Director of Mexico City Government
Alejandro Del Mazo Maza	2015–2018	Business Management	Federal Congressman (Suplent Plurinominal)	Underprosecutor of Natural Resources, PROFEPA		

Table 3.4 Evaluation of the trajectories of National Commissioners of Natural Protected Areas CONANP from 1994 to 2018

Name	Period	Profession	Previous job (−1)	Previous job	Subsequent job	Subsequent job (+1)	Total	PI
Javier de la Maza Elvira	1994–2000	3	3	3	3	3	15	1.00
Ernesto Enkerlin Hoeflich	2000–2011	3	3	3	3	3	15	1.00
Luis Fueyo Mac Donald	2011–2015	2	3	3	3	3	14	0.93
Alejandro Del Mazo Maza	2015–	1	1	2	0	0	4	0.27

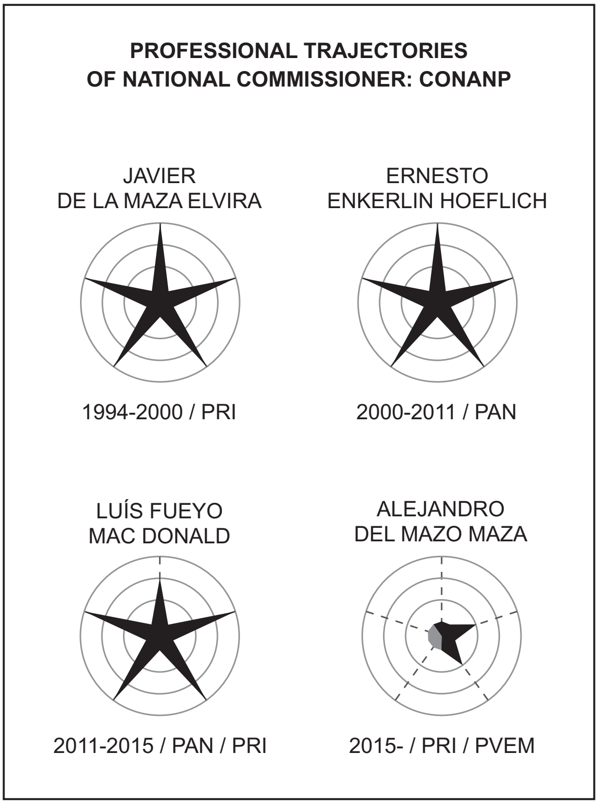

Fig. 3.4 Professional trajectories of National Commissioners: CONANP

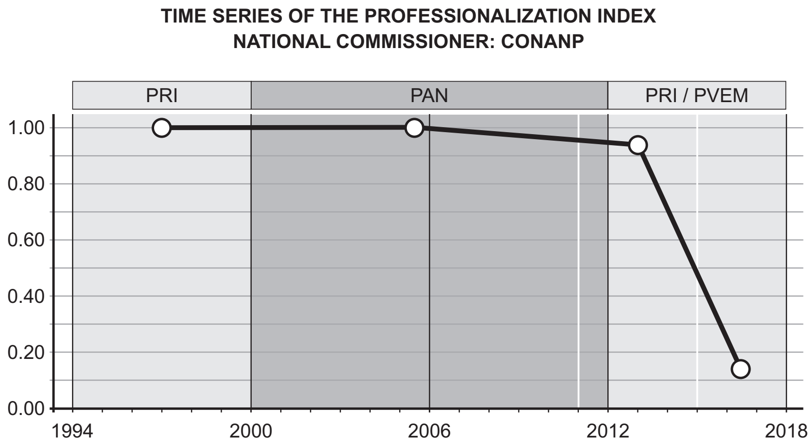

Fig. 3.5 Time series of the professionalization index – National Commissioners: CONANP

3.4 Mexican Government in Two Contexts: Other Countries and Mexican Nonprofit Organizations

To put in context the Mexican situation regarding the capacities of government officers that deal with the public management of natural resources and conservation, it is interesting to compare with other countries, as well as with the capacities and professionalization that is being developed by the private sector—as NGOs or self-organized civil society—on the very same subjects. When applying our analysis to high-rank officers from the environmental sector of a selection of other countries, it is shocking to observe that the same great differences observed in the long term within Mexico exist as well between diverse countries at the same time, i.e., in the present times (Table 3.7). The State Secretary of Germany in charge of the environment and nature conservation, Jochen Flashbarth, has a very high professionalization index: 0.93. This score contrasts extremely with the score of the Environment Ministry of Argentine, Rabine Sergio Berman, and Scott Pruitt, the head of the Environmental Protection Agency from the US federal government; the two of them have PI scores of 0.07. As well, not from the PI minimum are the actual ministers of Brazil (0.2), Canada (0.13), Chile (0.27), and Mexico (0.27) (Tables 3.7 and 3.8, and Fig. 3.8).

Having dedicated his life to nature's protection, France's Minister of Environment, Nicolas Hulot, was recently appointed by President Emmanuel Machron. Even though Hulot has not a university formation, because of his vast experience on environmental issues previous to get the minister responsibility he also gets a high PI score of 0.73. A summary of the comparative analysis among our countries' selection is presented in Fig. 3.9.

These comparative results are overall very concerning. For Mexico the most troublesome part is getting such a low score in the PI. Putting this result in the context of the international arena makes it even worse. The comparison with Germany

Table 3.5 Trajectories of National Commissioners of Fisheries CONAPESCA (before SEMARNAP and SEPESCA) from 1976 to 2018

Name	Period	Profession	Previous job (−1)	Previous job	Subsequent job	Subsequent job (+1)
Fernando Rafful Miguel	1976–1982	Economist	Undersecretary of National Patrimony	Senator by the state of Campeche	Advisor to the Secretary of Fisheries	Government Secretary from the state of Campeche
Pedro Ojeda Paullada	1982–1988	Lawyer	President of the PRI party	Secretary of Work	President of the National Commission of Food	President of the Mexican Geography Society
María de los Ángeles Moreno Uriegas	1988–1991	Economist	Undersecretary of Social and Rural Development from the Secretary of Budget	Undersecretary of Social and Regional Development from the Secretary of Budget	Federal Congressman	Secretary and President of the PRI party
Guillermo Jiménez Morales	1991–1994	Lawyer	Governor of the state of Puebla	Federal Congressman	Ambassador to the Vatican State	Undersecretary of Religious Matters
Julia Carabias Lillo	1994–2000	Biology with postgraduate course in Ecology	Ecology Researcher UNAM	President of the National Institute of Ecology	Ecology Researcher UNAM	Ecology Researcher UNAM and conservation projects
Jerónimo Ramos Sáenz-Pardo CONAPESCA	2000–2003	Economy with postgraduate courses	Director General of International Fisheries Affairs SEPESCA	Director General of Fisheries Management	Director General of Maricultura del Norte (private company)	Consultant
Ramón Corral CONAPESCA	2003–2011	Unfinished studies in engineering	Candidate for Governor of the State of Sonora (lost)	Senator of the State of Sonora PAN	Private	Pre-candidate for Senator of the State of Sonora PAN
Mario Gilberto Aguilar Sánchez CONAPESCA	2012–2018	Lawyer	Diplomatic Minister for environmental, social, development, and fisheries matters. Mexican Embassy in Washington, D.C.	Private matters		

Table 3.6 Trajectories of National Commissioners of Fisheries CONAPESCA (before SEMARNAP and SEPESCA) from 1976 to 2018

Name	Period	Profession	Previous job (−1)	Previous job	Subsequent job	Subsequent job (+1)	Total	PI
Fernando Rafful Miguel	1976–1982	2	2	1	3	1	9	0.60
Pedro Ojeda Paullada	1982–1988	1	0	1	2	1	5	0.33
María de los Ángeles Moreno Uriegas	1988–1991	2	2	2	1	0	7	0.47
Guillermo Jiménez Morales	1991–1994	1	0	1	0	0	2	0.13
Julia Carabias Lillo	1994–2000	3	3	3	3	3	15	1.00
Jerónimo Ramos Sáenz-Pardo	2000–2003	2	3	3	2	2	12	0.80
Ramón Corral Ávila	2003–2011	0	1	0	0	0	1	0.07
Mario Gilberto Aguilar Sánchez	2012–2018	1	1	0	0	0	2	0.22

and France is very revealing. Even though Mexico is recognized as one of the few megadiverse countries in the world, our secretary of state PI—formation and experience—is only one fraction of the PI from the German and French officers. Focusing on the international arena as such, it is also very concerning to observe through the formal analysis that even some of the most developed countries, with a rich nature and abundant natural resources, are being currently managed by public officers that have very limited professional credentials for the post, i.e., the USA and Canada.

These results show that, much more common than what we could expect, the construction of a rational state whose structure and functions are based on its anticipated ability to take care in a sustainable way of the country's natural resources and the conservation of nature is severely questioned by the unquestionable facts: the personal constraints of the officers being appointed to supposedly exercise a mandate in favor of the people of their countries. Not being such rationality the prevailing one—in Mexico and other countries as well—the following question comes into view immediately: What is then the prevailing rationality? Two responses appear as plausible: (1) It is about that intentionally and from the highest levels of the state, depredation of natural resources is being facilitated, for the sake of favoring private interests, or (2) Chaotic and centrifugal forces derived from the lack of

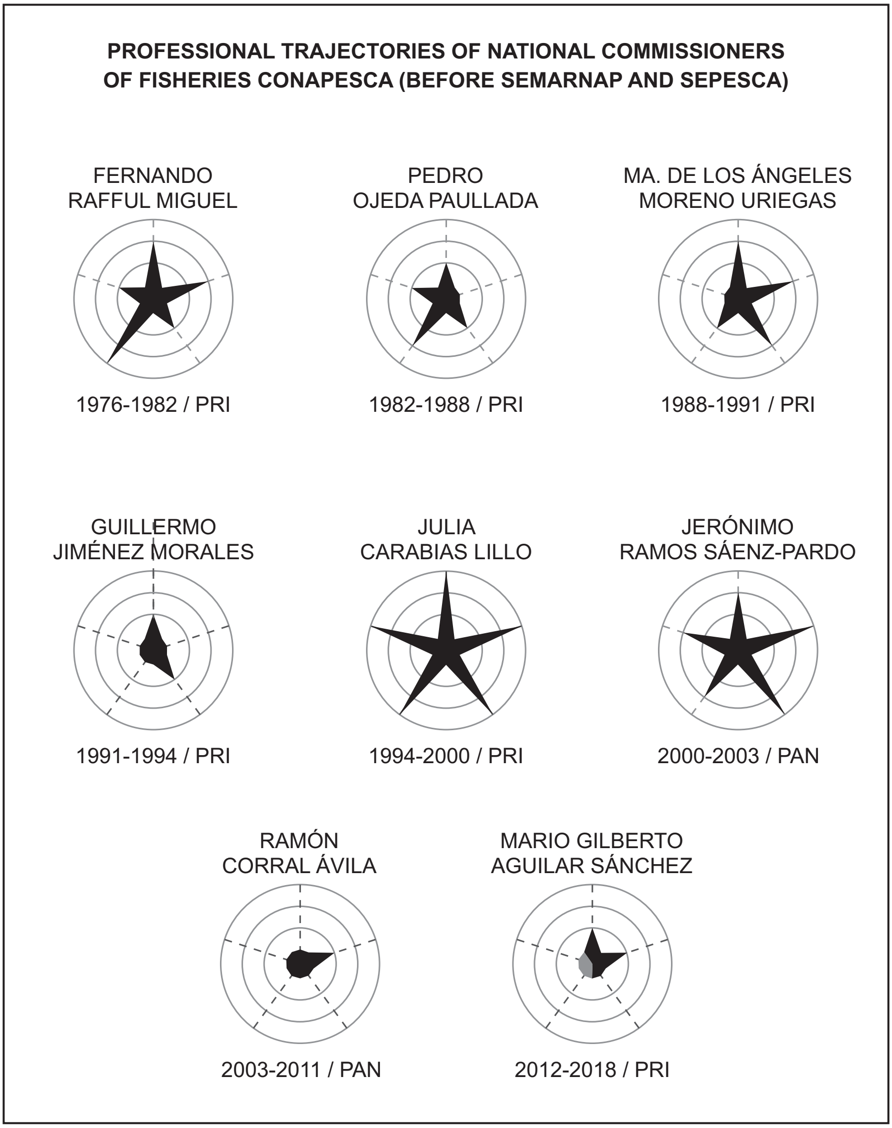

Fig. 3.6 Professional trajectories of National Commissioners of Fisheries: CONAPESCA (Befores SEMARNAP and SEPESCA)

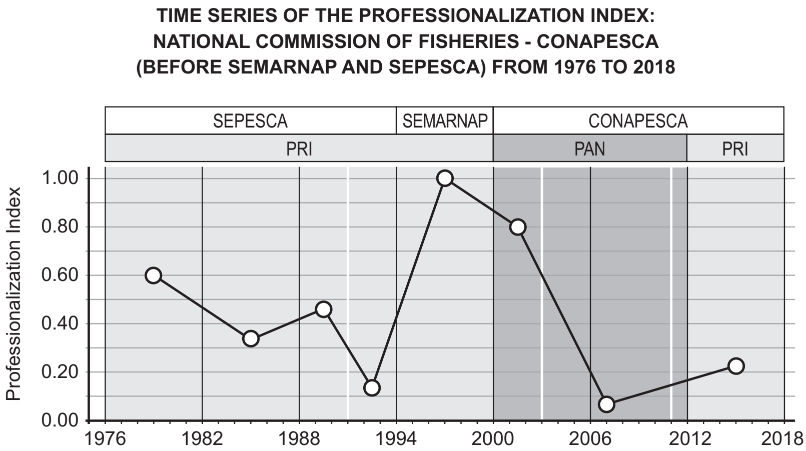

Fig. 3.7 Time series of the professionalization index: National Commission of Fisheries – CONAPESCA (Before SEMARNAP and SEPESCA) from 1976 to 2018

social and political cohesiveness allow the possibility of such very unfitted appointments, disregarding the consequences. Countries with modern and well-structured democracies—strong checks and balances and where the rule of law used to prevail—and not linked to patrimonial traditions, e.g., the USA and Canada, are suffering as well with poor appointments that resemble patrimonialism.

By analyzing as another context the professionalization of the self-organized society, in the form of well-structured and specialized nonprofit organizations, within contemporary Mexico, we can also put in perspective the Mexico's government situation. The studied NGOs from northwest Mexico are specialized in the subject matters of conservation, natural resource management, and sustainable development. Already accumulating a history in the order of decades, they are being consolidated as professionalized organizations, with full-term staff recruited because of capacities and merits. The executive directors' biographies proof that (Table 3.9).

The executive directors' PI of the NGO's selected group gets all of them the highest possible scores: 1.0 (Table 3.10 and Fig. 3.10). The contrast with federal government officers—and with officers from other countries as well—could not be more extreme.

The conclusions of our analysis come out naturally and are evident:

1. The government's ideology of contemporary Mexico shows clear indicators of a strong patrimonialism culture. President Peña Nieto, resembling a king, appoints his cousin, Alejandro Del Mazo Maza, resembling a prince, as the head of the National Commission of Natural Protected Areas (CONANP), having very limited credentials for the high public responsibility. This is an obvious indicator that the private interests and spheres rule above the public interest.

Table 3.7 Trajectories of high-rank government officers from the environmental sector of diverse countries

Country	Name and office	Period	Profession	Previous job (−1)	Previous job	Subsequent job	Latter job (+1)
Germany Secretary	Jochen Flasbarth—State Secretary at the Federal Ministry for the Environment, Nature Conservation, Building, and Nuclear Safety	2013–	Economy	Director General for Nature Conservation and Sustainable Use of Natural Resources. Minister of the Environment, Nature Conservation, and Nuclear Safety	President of the Federal Environment Agency		
Argentina	Rabine Sergio Bergman—Minister of Environment and Sustainable Development	2015–	Pharmacy (BSc) and Rabbinical Seminary	Rabbi of Temple Freedom	National Congressman		
Chile	Jorge Canals—Minister of Environment	2017	Law (BSc and MA)	Chief of Staff of the Metropolitan Head	Undersecretary of Environment		
France	Nicolas Hulot—Minister of Ecological and Solidary Transition	2017	No university diploma	Journalist. Ushuaia Foundation/Foundation Nicolas Hulot	Europe Écologie-Les Verts primary election for the 2012 French presidential candidate (lost)		
Canada	Catherine McKenna—Minister of Environment and Climate Change	2015–	Law, MSc, PhD	UN Peacekeeping Mission on the Timor Sea Treaty	International trade lawyer		
Colombia	Luis Gilberto Murillo—Minister of Environment	2016	Mining (BSc) and Mining Engineering (MSc)	Governor of Chocó	Coordinator of Presidential Development Program "Todos Somos Padfim"		

USA	Scott Pruitt—Environmental Protection Agency Administrator	2017	Political Science and Communications (BSc); Law (PhD)	Oklahoma State Senator (1998–2007), co-owner and managing general partner of the Oklahoma RedHawks baseball team	Attorney General for Oklahoma		
Brazil	José Sarney Filho—Minister of Environment	2013–	Law	State Congressman of Maranhão	Federal Congressman		
Mexico	Rafael Pacchiano Alamán	2012–2018	Industrial Engineer	Plurinominal Federal Congressman	Undersecretary of Environmental Protection		

Table 3.8 Evaluation of the trajectories of high-rank government officers from the environmental sector of diverse countries

Country	Name and office	Period	Profession	Previous job (–1)	Previous job	Subsequent job	Subsequent job (+1)	Total	IP
Germany Secretary	Jochen Flasbarth—State Secretary at the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety	2013–	2	3	3	3	3	14	0.93
France Minister	Nicolas Hulot—Minister of Ecological and Solidary Transition	2017	0	3	2	3	3	11	0.73
Colombia Minister	Minister for Environment and Sustainable Development	2016	1	2	2	1	1	7	0.47
Mexico Secretary	Rafael Pacchiano Alamán	2012–2018	0	1	3	0	0	4	0.27
Chile Minister	Jorge Canals—Minister of Environment	2017–	1	0	3	0	0	4	0.27
Brazil Minister	José Sarney Filho—Minister of Environment	2015–	1	1	1	0	0	3	0.20
Canada Minister	Catherine McKenna—Minister of Environment and Climate Change	2015–	1	1	0	0	0	2	0.13
Argentina Minister	Rabine Sergio Bergman—Minister of Environment and Sustainable Development	2015–	0	0	1	0	0	1	0.07
USA EPA	Scott Pruitt—Environmental Protection Agency Administrator	2017–	1	0	0	0	0	1	0.07

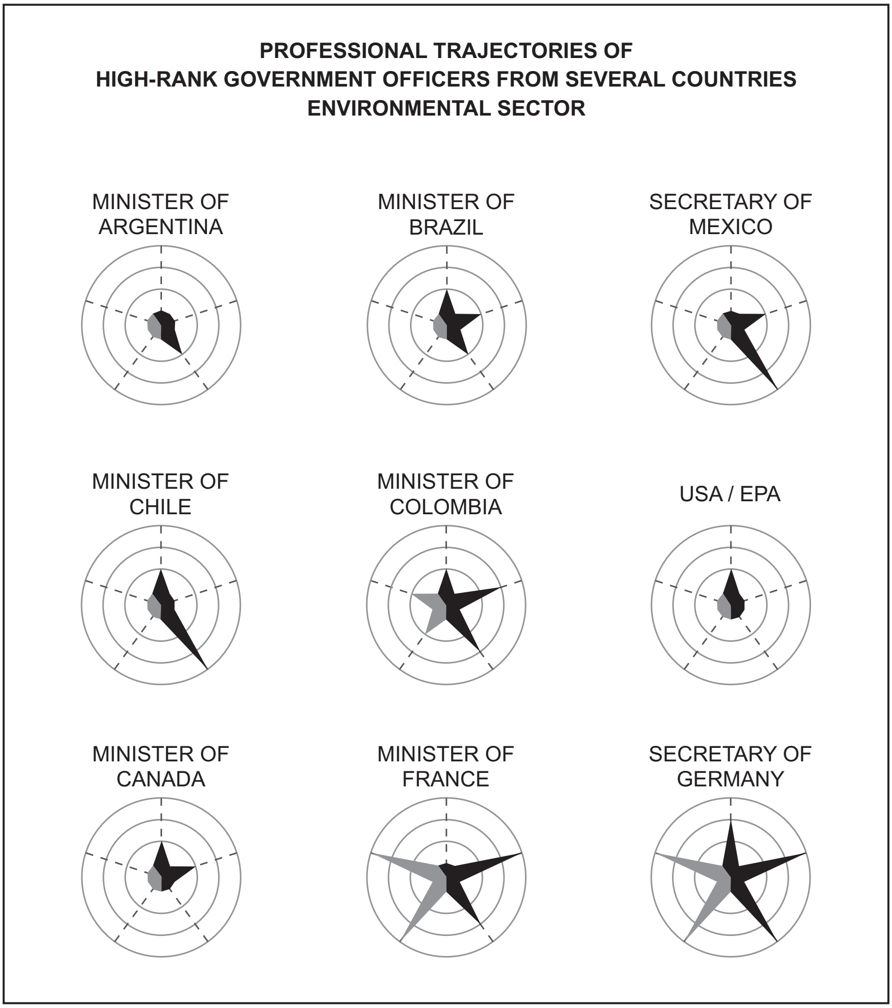

Fig. 3.8 Professional trajectories of high-rank government officers from several countries environmental sector

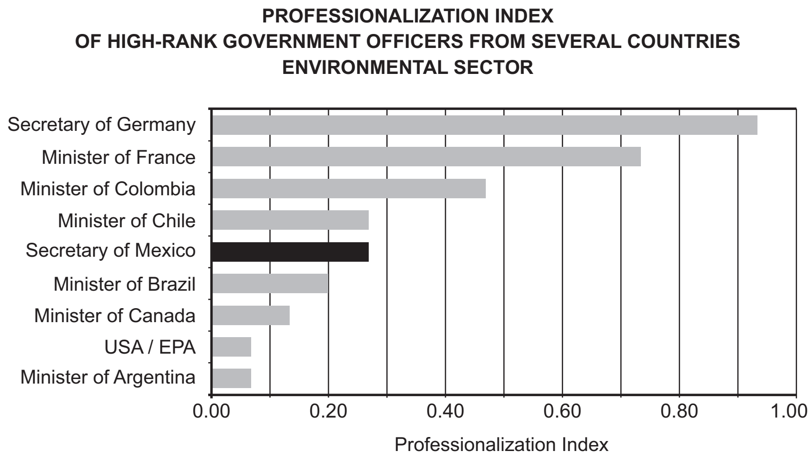

Fig. 3.9 Professionalization index of high-rank government officers from several countries – environmental sector

2. The lack of a real and legally binding civil service for the federal government environmental sector appears as an important component to improve governance and achieve tangible conservation and measurable sustainable goals.
3. Organized civil society in Mexico is already marking a pace. With their professionalization and recruitment by merits, Mexican environmental NGOs are offering an example to government structures.
4. The international contemporary context in these days is not the most favorable one to induce or model positive changes in Mexico's government structures and processes. For instance, the US government, usually setting benchmarks in that regard—as establishing a civil service act 135 years ago with the Pendleton Act (US Congress 1883)—is currently experiencing an accelerated governance regression, including the historic dismantling of the Environmental Protection Agency.
5. While establishing a civil service act for the environmental sector in Mexico seems to be an important contribution, it is not possible to consider that such a measure alone can produce all the required conditions for a comprehensive and long-lasting impact. Other governance measures, including checks and balances, accountability to the citizens and public scrutiny, and proper budgets, are also crucial.

Table 3.9 Trajectories of Executive Directors from NGOs Environmental Sector NW Mexico

Name	Period	Profession	Previous job (−1)	Previous job	Subsequent job	Subsequent job (+1)
Gustavo Danemann, Executive Director, Pronatura NW	2007–	Marine Biology (BSc, UABCS); Marine Ecology (MSc, CICIMAR); Natural Resources Administration and Policy Analysis (PhD, UABC); Nonprofit NGO Management (Diploma, Stanford)	Project Coordinator – Biodiversity conservation –Pronatura Península de Baja California (1997–2002)	Conservation Director, Pronatura Noroeste (2002–2007)		
Federico Alfonso Méndez Sánchez, Executive Director, Grupo de Ecología y Conservación de Islas (GECI)	2017–	Oceanography (BSc, UABC); Environmental Management (Postgraduate Diploma), Environmental Management (MSc, Univ. of Auckland) and Natural Resources Management (PhD Cand., CIBNOR)	Director of Development, Grupo de Ecología y Conservación de Islas, A.C. (2010–2015)	Adjunct Executive Director, Grupo de Ecología y Conservación de Islas, A.C. (2016–2017)		
Eduardo Nájera Hillman, Program Director Mexico, COSTASALVAjE	2012–	Biology (BSc, UNAM); Conservation Ecology and Natural Resource Management (PhD, NZ)	Lecturer/Researcher, School for Field Studies, Coastal Ecology. Puerto San Carlos, BCS, Mexico. 2010–2011	Postdoctoral Fellow, Vertebrate Research Network at the Instituto de Ecología (INECOL) (2011–2012)		
Jorge Torre Cosío, Executive Director, Comunidad y Biodiversidad (Cobi)	2007–	Biochemistry and Aquatic Resources Management (BSc, ITESM, 1991); Marine Ecology, Conservation and Management of Natural Resources (MSc, ITESM, 1995) and Ecology and Natural Resources (PhD, Univ. Of Arizona, 2002)	Coordinator of Research and Information and Founder Member, Comunidad y Biodiversidad, A.C. (1999–2004)	Operations Director, Comunidad y Biodiversidad, A.C. (2005–2007)		

(continued)

Table 3.9 (continued)

Name	Period	Profession	Previous job (−1)	Previous job	Subsequent job	Subsequent job (+1)
Meredith de la Garza, Executive Director, Executive Director, Sociedad de Historia Natural Niparajá, A.C.	2012–	Law and International Relations (BSc.); Environment and Education (MSc)	Project Coordinator at Sociedad de Historia Natural Niparajá, A.C. (2008–2009)	Conservation Program Coordinator at Sociedad de Historia Natural Niparajá, A.C. (2009–2012)		
Fernando Ochoa Pineda, Executive Director, Defensa Ambiental del Noroeste (DAN)	2004	Law (BSc, UIC); Environmental Law and Policy (Diploma, UEPD); Criminal Law (Diploma, INACIPE)	Practicing Attorney (constitutional, labor and criminal law). Abogados Asociados Law Firm. Mexico City. (1998–2002)	Legal Advisor, Private Land Conservation Program Pronatura Noroeste, A.C. (2002–2004)		

Table 3.10 Evaluation of the trajectories of Executive Directors from NGOs Environmental Sector NW Mexico

Name and NGO	Period	Profession	Previous job (–1)	Previous job	Subsequent job	Subsequent job (+1)	Total	IP
Gustavo Danemann, Executive Director, Pronatura NW	2007–	3	3	3	3	3	15	1.00
Federico Alfonso Méndez Sánchez, Executive Director, GECI	2017–	3	3	3	3	3	15	1.00
Eduardo Nájera Hillman, Program Director Mexico, COSTASALVAjE	2012–	3	3	3	3	3	15	1.00
Jorge Torre Cosío, Executive Director, Cobi	2007–	3	3	3	3	3	15	1.00
Meredith de la Garza, Executive Director, Niparajá	2012–	3	3	3	3	3	15	1.00
Fernando Ochoa Pineda, Executive Director, DAN	2004	3	3	3	3	3	15	1.00

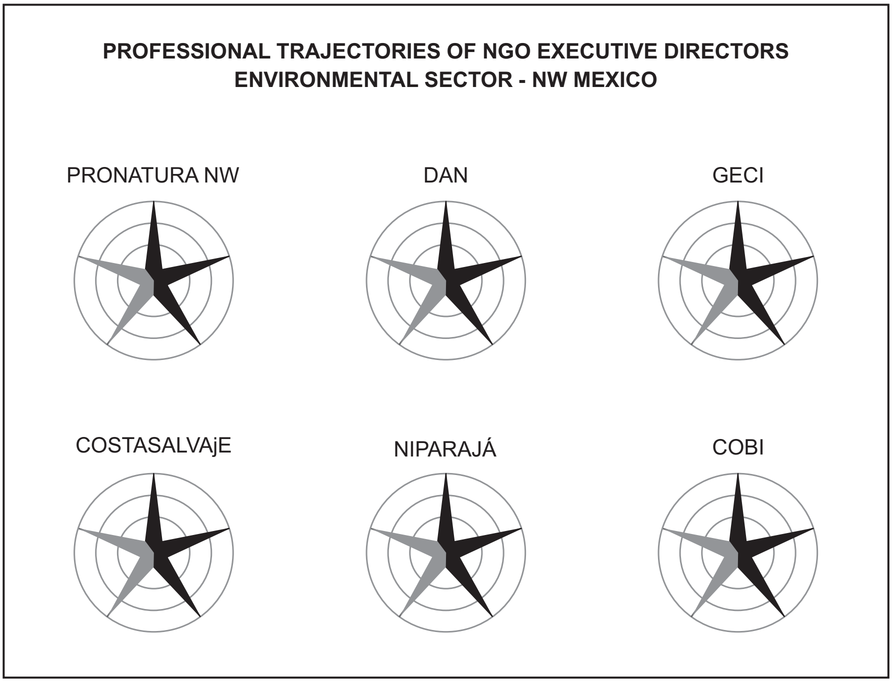

Fig. 3.10 Professional trajectories of NGO Executive Directors Environmental Sector – NW Mexico

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Chapter 4
Public Policies and Biodiversity Conservation in Mexico

Norma Patricia Muñoz Sevilla, Maxime Le Bail, and Omar Berkelaar Muñoz

Abstract Life in this planet is a big concern for humanity, and biodiversity conservation is, without any doubt, one of the major key components to preserve life on Earth. Since Rio 1992, many actions, efforts, and instruments were developed and adopted to face the challenge of biodiversity conservation, such as the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change, the Millennium Development Goals, 2030 Agenda, the Strategic Plan for Biodiversity 2011–2020 and its Aichi Biodiversity Targets, the Implementation of Biodiversity, the Paris Agreement, the Marrakech Action Proclamation, and the Cartagena and Nagoya Protocols, among others. In addition to international compromises, every country member of the UNFCCC has its own legal instruments to protect and conserve biodiversity. Mexico is one of those countries with the high responsibility as a megadiverse country.

Keywords Biodiversity conservation · Public policies · Mexico

4.1 Introduction

> The President of the Republic, Enrique Peña Nieto, signed today the Decree of the Revillagigedo National Park, with which the Government of Mexico fulfills its commitment to ensure the conservation of this exceptional archipelago, and that will allow the conservation of hundreds of marine species, many of them at risk. (Gobierno de la República 2017)

Mexico harbors almost 10% of the species registered in the world, and many of them are endemic.

According to Llorente-Bousquets and Ocegueda (2008), it is the second most diverse country

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in the world for reptiles, the third for mammals, the fifth for vascular plants and amphibians, and the eleventh for birds.

In order to conserve this natural richness, Mexico is part of the international efforts of the Convention on Biological Diversity. Since 2002, it is a member of the group of Like-Minded Megadiverse Countries.

On the other hand, Mexico has developed an important national legal framework.

This chapter presents the international framework for biodiversity conservation Mexico is part of, the legal structure in Mexico on this subject, and the strategies and programs of the federal government and gives some relevant case studies in the country.

4.2 International Framework for Biodiversity Conservation

4.2.1 The Convention on Biological Diversity

The Convention on Biological Diversity defines biodiversity or biological diversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part of; this includes diversity within species, between species and of ecosystems" (CBD 2007).

In order to protect the biodiversity around the planet, the United Nations established in 1992 the Convention on Biological Diversity, whose objectives are "the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising out of the use of genetic resources, including appropriate access to genetic resources and transfer of relevant technologies, taking into account all rights over those resources and technologies, and by appropriate funding" (United Nations 1992).

The Convention includes 42 articles to settle the objectives, the use of terms, the principle, the jurisdictional scope, the cooperation, the general measures for conservation and sustainable use identification and monitoring, *in situ* conservation, *ex situ* conservation, the sustainable use of components of biological diversity, incentive measures, research and training, public education and awareness, impact assessment and minimizing adverse impacts, access to genetic resources, access to technology transfer, information exchange, technological and scientific cooperation, handling of biotechnological and distribution of its benefits, financial resources, financial mechanism, relationship with other international conventions, the Conference of the Parties, its secretariat, its subsidiary body on scientific, technical, and technological advice, its reports the settlement of disputes, the adoption of protocols, the amendment of the convention or protocols, the adoption and amendment of annexes, the right to vote, the signature, the ratification, the acceptance or approval, the accession, the entry into force, the reservations, the withdrawals, the financial interim arrangements, the secretariat interim arrangements, and the depositary and authentic texts. The two annexes define, on the one hand, the identification and monitoring and, on the other hand, the arbitration.

After the CBD from 1992, we can find out other instruments developed for biodiversity conservation: Agenda 2030, Implementation of the CBD program, the Strategic Plan for Biodiversity 2011–2020 and its Aichi Biodiversity Targets, and the related Cartagena and Nagoya Protocols, among others.

4.2.2 The 2030 Agenda for Sustainable Development

After the Millenium Development Goals adopted in 2000 (UNDP 2000) to reduce extreme poverty, supported with a series of eight time-bound targets as follows: 1) To eradicate extreme poverty and hunger; 2) To achieve universal primary education; 3) To promote equality gender and empower women; 4) To reduce child mortality; 5) To improve maternal health; 6) To combat HIV/AIDS, malaria, and other diseases; 7) To ensure environmental sustainability, and 8) To develop a global partnership for development—the Sustainable Development Goals were adopted in September 2015 by 170 countries (2030 Agenda for Sustainable Development), and the Agenda is a "plan of action for people, planet and prosperity," with 17 Sustainable Development Goals and 169 targets which will take action over the following 15 years.

2030 Agenda goals:

1. End poverty in all its forms everywhere.
2. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
3. Ensure healthy lives and promote well-being for all at all ages.
4. Ensure inclusive and equitable quality education, and promote lifelong learning opportunities for all.
5. Achieve gender equality and empower all women and girls.
6. Ensure availability and sustainable management of water and sanitation for all.
7. Ensure access to affordable, reliable, sustainable, and modern energy for all.
8. Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
9. Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
10. Reduce inequality within and among countries.
11. Make cities and human settlements inclusive, safe, resilient, and sustainable.
12. Ensure sustainable consumption and production patterns.
13. Take urgent action to combat climate change and its impacts.
14. Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.

15. Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.
17. Strengthen the means of implementation, and revitalize the global partnership for sustainable development.

4.2.3 Strategic Plan for Biodiversity (SPB) 2011–2020 and the Aichi Targets

The SPB is a complex plan with a vision, a mission, strategic goals, and 20 targets known as “Aichi Targets” (UN 2011–2020).

Vision: “by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essentials for all people.”

Mission: “Take effective and urgent action to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet’s variety of life, and contributing to human well-being, and poverty eradication. To ensure this, pressures on biodiversity are reduced, ecosystems are restored, biological resources are sustainably used and benefits arising out of utilization of genetic resources are shared in a fair and equitable manner; adequate financial resources are provided, capacities are enhanced, biodiversity issues and values mainstreamed, appropriate policies are effectively implemented, and decisión-making is based on sound science and the precautionary approach.”

The Aichi Biodiversity Targets

Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society, with four targets.

Strategic Goal B: Reduce the direct pressures on biodiversity, and promote sustainable use, with six targets.

Strategic Goal C: Improve the status of biodiversity by safeguarding ecosystems, species, and genetic diversity, with three targets.

Strategic Goal D: Enhance the benefits to all from biodiversity and ecosystem services, with three targets.

Strategic Goal E: Enhance implementation through participatory planning, knowledge management, and capacity building, with four targets.

The biodiversity conservation actions in Mexico, in addition to the international instruments and the adopted compromises, are supported by three main programs:

Natural Protected Areas (NPAs), Land Use (Territory ordinance) and Marine Spatial Planning (MSP), and NPA Management Program.

4.3 The Legal Framework for Biodiversity Conservation in Mexico

4.3.1 The Constitution

Biodiversity preservation in Mexico is considered at the level of its Constitution (Cámara de diputados del H. Congreso de la Unión 1917), the maximum legal body, from which all laws, statutes, and codes are derived.

Four articles of the Constitution state the legal framework for environmental matters:

- Article 4 guarantees to everyone the right to count with a healthy environment for his development and welfare.
- Article 25 states that the development of public and private companies shall be encouraged under social equality, productivity, and sustainability criteria, considering the public interest and the use of productive resources and caring for its conservation and the environment.
- Article 27 expresses that the ownership of lands and waters within the limits of the national territory originally corresponds to the Nation and that this one will have at any time the right to impose on private property the modalities dictated by the public interest, as well as to regulate, for social benefit, the use of natural elements susceptible to appropriation. As a consequence, the Nation will be authorized to dictate the necessary measures to preserve and restore the ecological balance, among others.
- Article 73 gives to the Congress the faculty to […] "issue laws that establish the concurrence of the Federal Government, the governments of the federal entities, of the Municipalities and, where appropriate, of the territorial demarcations of Mexico City in matters of environmental protection and ecological balance preservation and restoration."

These articles give the legal support for the creation of environmental laws in Mexico.

Regarding biodiversity conservation, the main law currently in force in Mexico is undoubtedly the General Law for Ecological Equilibrium and Environmental Protection.

4.3.2 *The General Law for Ecological Equilibrium and Environmental Protection (LGEEPA) and its Regulations*

The LGEEPA (Cámara de diputados del H. Congreso de la Unión 1988a) has been published in the Official Gazette in 1988. It is the main law for environmental protection in Mexico, and almost all the laws related to environment and biodiversity currently existing in the country refer to it.

This Law regulates the provisions of the Constitution that refer to the preservation and restoration of the ecological balance, as well as to the environmental protection, along the national territory. Its provisions, of public order and social interest, aim to promote sustainable development and establish the bases for the biodiversity preservation and protection, as well as to create and manage natural protected areas, among others.

It establishes the mechanisms for the coordination of the three levels of government and delimits their faculties and determines the environmental policy of the country and its respective instruments for ecological planning, finance, urban development, and human settlements, among others.

It also defines the concept of natural protected areas, sets their objectives and the National System for Natural Protected Areas, and classifies them into the following:

I. Reserves of the biosphere
II. National parks
III. Natural monuments
IV. Areas for protection of natural resources
V. Areas for flora and fauna protection
VI. Sanctuaries
VII. Parks and State Reserves, as well as other categories established by the local legislations
VIII. Municipal ecological conservation zones, as well as other categories that establish local legislations
IX. Areas voluntarily destined for conservation

For each of them, a core zone and an absorption zone are defined. The core zones for protection only allow scientific research and monitoring and, in the case of core zones for restrict access, low impact tourism. At the same time, the main function of the absorption zones is to guide the exploitation activities which are carried out there, toward sustainable development, while creating the necessary conditions to achieve the long-term conservation of the ecosystems of the latter.

Finally, the LGEEPA is regulated by six bylaws (Cámara de diputados del H. Congreso de la Unión. 1988b, 2000a, b, 2003a, 2004, 2010): the Regulation of the LGEEPA for Prevention and Control of Atmospheric Pollution, the Regulation of the LGEEPA for Natural Protected Areas, the Regulation of the LGEEPA for Environmental Impact Assessment, the Regulation of the LGEEPA for Ecological

Planning, the Regulation of the LGEEPA for Emissions and Transfer of Contaminants Registry, and the Regulation of the LGEEPA for Self-Regulation and Environmental Audits.

4.3.3 The General Law for Wildlife (LGVS)

In 2000, the LGVS (Cámara de diputados del H. Congreso de la Unión. 2000c) has been published to conserve wildlife and its habitat through the protection and the demand of optimum levels of sustainable use, so that simultaneously it is possible to maintain and promote the restoration of its diversity and integrity and to increase the welfare of the inhabitants of the country, complementing the LGEEPA.

The LGVS states that it is the duty of all the inhabitants of the country to conserve wildlife and that any act that implies its destruction, damage, or disturbance to the detriment of the interests of the Nation is forbidden.

It forms the national policy on wildlife and its habitat and sets up the concurrence of the federative entities, the Municipalities, the city of Mexico, and the federal government in that matter.

It also encourages the participation of all the people and sectors involved in the formulation and application of the measures for the conservation and sustainable use of the wildlife, as well as the development of environmental education programs, training, professional training, and scientific and technological research). It aims to involucrate particularly the rural communities that involve traditional lifestyles relevant to the conservation and sustainable use of wildlife and their habitat and will promote its wider application with the approval and participation of those who possess that knowledge, innovations, and practices.

4.3.4 The General Law for Sustainable Forest Development (LGDFS)

The LGDFS (Cámara de diputados del H. Congreso de la Unión 2003b) was published in the Official Gazette on February 25, 2003, and recognizes that the sustainable forestry development is considered a priority area of development national.

It aims to regulate and promote the conservation, protection, restoration, production, management, cultivation, management, and use of the forest ecosystems of the country and its resources, as well as to distribute the competences that correspond to the Federation, the States, the Federal District, and the Municipalities.

The general goals of this law are:

I. To contribute to the social, economic, ecological, and environmental development of the country, throughout the integral sustainable management of forest resources, as well as hydrological and forest basins and ecosystems, without prejudice to the provisions of other systems

II. To promote silviculture and the use of forest resources, to ensure the improvement of Mexicans' standard of living
III. To develop environmental goods and services and protect, maintain, and increase the biodiversity provided by forest resources
IV. To promote the organization, operational capacity, integrality, and professionalization of the public institutions of the Federation, States, Federal District, and Municipalities, for sustainable forestry development
V. To respect the right to the preferential use of the forest resources of the places inhabited by the indigenous communities

For this, it creates the National Forest Service that is integrated by the Minister of Environment, the Minister of Defense, the Minister of Agriculture, the Governors and the Mayor of Mexico City, the Head of the National Forest Commission, and the Federal Attorney for Environmental Protection and counts with several working groups.

It also establishes the bases) of several instruments as the forestry development planning, the National Forest Information System, the National Forest and Soil Inventory, the Forest Zoning, the National Forest Registry, the Annual Satellite Survey of the Forest Coverage Index, and the context for emitting Mexican official standards on this subject.

Finally, it sets the legal framework for the management and sustainable use of the forest resources, as well as for their conservation, taking into account the different ways to encourage it throughout social participation and surveillance.

4.3.5 The Federal Law for the Sea

The Federal Law for the Sea was published in 1986 and establishes the legal framework for the Mexican marine zones, including the conservation and use of marine biodiversity, and is complemented by a bylaw on marine pollution prevention.

4.3.6 Other Laws

Several other existing laws at the federal level contribute directly or undirectly to biodiversity conservation: the Planning Law, the Biosecurity Law for Genetically Modified Organisms, the General Law for Prevention and Integrated Waste Management, the Law for Rural Sustainable Development, the General Law for Sustainable Aquaculture and Fisheries and its two regulations, the Organic Products Law, the National Waters Law, and the General Law for tourism, among others.

4.3.7 The Proposal of General Law for Biodiversity

An important law initiative on biodiversity is currently being considered by the Congress: the General Law for Biodiversity, whose main goal, according to its expository part, is to provide Mexico with a legal instrument that encompasses biodiversity at its three levels, genes, species, and habitats.

The proposal aims to incorporate the provisions of the Convention on Biological Diversity, specifically the Nagoya Protocol, within the Mexican legal framework, as well as to integrate in one single document the several provisions on biodiversity.

However, this proposal is being strongly criticized; it is reproached to present important shortcomings that, far from modernizing the legal framework, only copies, with important exceptions, the General Law for Wildlife and removes from the General Law of Ecological Balance and Environmental Protection the entire title that refers to the natural protected areas, among others. Academicians also alert that large part of the species is not taken into account by this proposal because of confusions and mistakes in the technical terms or omissions, in particular, amphibians, most of insects, parakeets, and sea turtles (Cantú 2018).

On January 2, 2018, the Senate approved the General Law for Biodiversity, and the Deputy Chamber is currently in the process to ratify this proposal before sending it to the Official Gazette of the Federation for its publication.

In addition to the Constitution and laws, the legal framework on biodiversity conservation in Mexico counts with several general provisions and legal standards, from which the NOM-059-SEMARNAT-2010 is one that deserves to be mentioned since it lists the species or populations of flora and fauna at risk in the Mexican Republic.

4.4 Federal Strategies and Programs for Biodiversity Conservation

At the beginning of each administration, the Executive builds the National Plan for Development, which aims to determine the main objectives of the whole Federal Public Administration.

The National Plan for Development 2013–2018 (Gobierno de la República 2013) states five national goals (Peace, Inclusion, Education Quality, Prosperity, and Global Responsibility), supported by three transversal strategies.

Within its national goal “Prosperity” (México Próspero), the Executive establishes Objective 4.4 to “Promote and guide an inclusive and facilitating green growth that preserves our natural capital while generating wealth, competitiveness and employment in an effective way.” To achieve this objective, several strategies are set up, in particular:

– Strategy 4.4.1 “To Implement a comprehensive development policy that links environmental sustainability with costs and benefits for society,” throughout the "update and align of the environmental legislation to achieve effective regulation of actions that contribute to the preservation and restoration of the environment and natural resources," and promoting "financing and investment schemes from different sources that multiply resources for environmental protection and natural resources"

– Strategy 4.4.3 "To strengthen the National Policy of Climate Change and care for the environment to move towards a competitive, sustainable, resilient and low carbon economy", thanks to the expansion of the infrastructure and environmental programs that guarantee public health and ecosystems and natural resources conservation
– Strategy 4.4.4 "To protect the national patrimony", by promoting the conservation, restoration, and use of the natural heritage, with innovative economic, financial, and public policy instruments; encouraging the knowledge on biodiversity and its conservation; increasing the surface of the national territory under conservation modalities, good productive practices, and regulated management of the natural heritage; focusing on biodiversity conservation programs and sustainable use of natural resources, to generate benefits in communities with high social and environmental vulnerability; improving reforestation schemes and instruments; as well as recovering ecosystems and deteriorated areas, among others

4.5 Conclusions

"However, even with all the legal instruments that environmental legislation has, Mexico presents serious problems to carry out conservation actions in environmental matters, and specifically on natural resources. These problems are not due to the lack of laws, regulations and norms, but to the lack of precision and coordination of these, and to the overlap in the attributions of the different dependencies and government levels. These legal instruments usually do not become applicable, since some of them are obsolete, overlap or are so general that they are not clear in real specific cases. In addition, there is the discretion that is conferred on the authority for its application or interpretation. The above results in the lack of observance of these measures by the population, either due to ignorance or due to the lack of importance attached to them" (CONABIO 1998).

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Chapter 5
Public Mexican Corporations' Sustainability Indicators: Measuring the Profit Benefits of Protected Natural Areas Programs for Socially Responsible Investors

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Abstract In the present chapter, we conduct an event-driven test of the implementation of a Natural Protected Area Program (NPAP) and the status of being socially responsible either in the profits or in the stock price of public corporations traded in the Mexican Stock Exchange. By using a panel regression model with yearly data from 2014 to 2016 of 33 companies, we found that even though the socially responsible status and the benefits of implementing a NPAP in a company are not priced by investors, the adoption of a NPAP creates, on average, an extra 13.38% ROI. Following our results, we suggest the level of NPAP implementation in a country as a potential sustainability (environmental) indicator be measured in panel regressions in different countries and to use such indicator as a portfolio asset allocation factor.

Keywords Socially responsible investment · Asset allocation · Natural protected areas · Environmental factors · Portfolio multifactor models · Panel data regression

5.1 Introduction

Socially responsible investment (SRI) is an emerging subject in financial economics, especially in the portfolio management due to the study of the risk-return efficiency of companies considered "socially responsible" or "sustainable."[1] This

[1] We will not discuss the appropriateness of the term sustainability or social responsibility by the fact that this issue, in the investment area, is a term used to qualify a company with high social, ethical, or environmental standards in the asset allocation process. That is, SRI investors only focus on the aforementioned management standards in order to include the security of a company or not. A brief review of the history of socially responsible investment practice in the literature review

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investment practice or strategy has notoriously evolved since the 1970s with protest against companies such as Dow Chemical[2] during the Vietnam War. In order to give a statement and to influence the financials of companies through credit or investment activities, the so-called socially responsible investment had its starting point in the investment portfolio process by excluding the securities issued by companies who were involved in the gun, tobacco, alcohol, or even high environmental impact companies such as oil, nuclear, or carbon energy industries, to mention a few examples. Even though this asset allocation inclusion/exclusion practice is not so new, it formally started in the financial markets with the creation of the Pax fund in the 1970s. SRI has had a historical influence of previous examples, such as the one of the Methodist Church in the 1920s that founded the Pioneer Fund (Renneboog et al. 2008). As noted, it is important to mention that this investment practice is not exclusive of the Methodist Church or social movements against war. It is an ancient and well-established practice in history. For example, Muslim people do not engage in credits or investments in companies related to pork, pornography, alcoholic beverages, or conventional banks. A similar investment selection processes happens with Jewish laws or some Indian precepts. Departing from this, socially responsible investment is accepted as an investment practice or screening process in which the investor invests her proceedings either in companies that fulfill the social responsibility criteria (positive stock screening or selection) or the exclusion of stocks from companies that are engaged in low ethical, low social responsibility, or high environmental impact activities (negative screening). This practice has increased so much that even public pension funds such as the Norwegian Public Pension Fund (NPF) or the California Public Employees Retirement System (CalPERS) have an investment policy engaged with SRI. Among the most relevant legal developments in the history of SRI, countries such as Belgium, Germany, Italy, the Netherlands, Sweden, and the UK have promoted SRI with regulation that included tax incentives or the mandatory adoption of SRI by institutional investors such as banks, insurance companies, or pension funds. For the specific case of Germany, the Netherlands, and Sweden, these countries passed bills and laws with tax incentives if SRI is performed (especially in renewable energies or organic farming). Belgium, Italy, and the UK passed laws that require pension funds to disclose the socially responsible motivations of their investment decisions.

Several studies to SRI have been published, as we will briefly review in the next section. Among these, the works of Bauer et al. (2005) and Derwall et al. (2011) make a review of the benefits and impact in the price of a stock if the issuing company is considered socially responsible or a member of a SRI index. In their reviews, they explain several hypotheses and causes related to asset pricing, and they suggest, as a possible investment selection explanation for SRI, that the benefits of SRI could not be priced by investors. Given this and given the trend by companies of sponsoring Natural Protected Areas Programs (henceforth NPAP), we are interested

section will give more insight of why sustainable investment and socially responsible investment are terms used indistinctly in this paper.

[2] Who invented NAPALM.

in measuring the impact of the environmental dimension (quantified with the adoption of NPAP in the company) in Mexican SRI public companies.

Departing from this motivation, we support the hypothesis that there is a direct benefit in the profits of Mexican socially responsible public companies (members of the sustainable IPC index) and, as a consequence, this benefit has an impact in the stock price, a situation that is not priced by the investors. This statistical relationship (the β_{NPAP} value for NPAP) will be our main NPAP indicator used in several countries for comparison purposes, as we will discuss in our conclusions.

Once we have stated the main goal and our hypothesis, we will proceed to briefly discuss the literature that motivates the present work, and after we will test our hypothesis in the empirical test section. Once we have reviewed our main results, we will present our conclusions and guidelines for future research, along with the basic NPAP indicator that we propose for SRI.

5.2 Literature Review

Since its more recent development in the 1970s, socially responsible investment (SRI) had the attention of several practitioners and academics given its social, ethical, and environmental benefits and also because it is a sort of "activist" investing strategy. Given this, it is expected that, as modern portfolio theory states, the socially responsible portfolios are less diversified than wider ones that also include the securities of non-socially responsible companies. As a result, this issue could lead to a less mean-variance efficient portfolio than the widely diversified one. This was the motivation for the first studies on the subject such as the ones of Moskowitz (1972) and Statman (2000). This last paper develops the first formal mean-variance review of SRI by testing the S&P500 against the Domini Social Index. His results showed over-performance in the accumulated return of the Domini index in the 1990–1998 and found no statistically significant differences in the risk-adjusted results. Following Statman and the development of SRI in several countries and in several pension funds, mutual funds, and institutional investors, many studies have tested the benefits of socially responsible investment against the conventional[3] or the "sinful" (non-SRI) one. Among the most relevant studies related to our paper, we mention the work of Schröder (2004, 2007) who tested the performance of 56 SRI mutual funds and 10 SRI benchmarks in the USA, the UK, Germany, and Switzerland. In these two papers he used the risk-adjusted returns and performance measures, the Huberman and Kandel (1987) spanning test in a one market factor CAPM auxiliary regression ($H_0 : \alpha = 0, \beta = 1$) and the Fama and French (1992) model with the panel data technique known as seemingly unrelated regression (SUR). He found no statistically significant evidence either against or in favor of SRI.

[3] That is the well-diversified investment strategy that includes securities of either socially responsible or non-socially responsible companies in the portfolio.

His conclusions also suggest that there is no mean-variance efficiency loss if the investor decides for a SRI strategy in her portfolio.

In a parallel review, Bauer et al. (2005) tested the US, UK, and German ethical funds by using the Carhart (1997) multifactor model in order to control the impact of the investment style (either market capitalization, momentum, or the growth-value style). Their results also suggest no over-performance of the SRI against the conventional one. These authors also gave three possible explanations to their findings related to market pricing process of SRI stocks:

1. Being a SRI company does not create or destroy value to the equity investor in a risk-return dimension.
2. SRI portfolios are worse performers than conventional ones by the fact that socially responsible investors increase the stock price with their demand, lowering the cost of capital.
3. SRI stocks over-perform conventional ones by the fact that investors do not price social responsibility.

Among these three explanations, we believe that SRI and NPAP's adoption is not priced by investors in the Mexican case.

From other previous studies, we found the one of Consolandi et al. (2008) who tested two theoretical portfolios from 1990 to 2006, one with the stock members of the Dow Jones Sustainability Stoxx Index (DJSSI) and another one with non-socially responsible members of the Stoxx 600. Their results showed that the non-socially responsible portfolio had a better performance than the SRI one. In order to complement their results, the authors made an event-driven study in order to determine the impact in the performance of a stock that is included or excluded in the DJSSI. Their conclusions suggested that the inclusion in the DJSSI is beneficial for the performance of the included stock, but the exclusion had deeper negative impacts, giving support to the second explanation of Bauer et al. (2005). That is, SRI is priced by investors, and, as a consequence, the price of the SRI stock moves high, given the stronger demand. In order to complement this last finding, Capelle-Blancard and Couderc (2009) tested again the inclusion and exclusion in 827 stocks in SRI indexes in the USA, the UK, Japan, Germany, and France. They found similar results to Consolandi et al. (2008), but they noted that the "atypical" price movement was observed only in the short term, and, in the long term, there was no evidence of this impact.

An interesting study that complements the two previous ones is the paper of Derwall et al. (2011) that suggested two possible theories for the pricing of SRI:

1. The *shunned-stock hypothesis* that states that SRI investors are ethics- or moral value-driven investors who prefer to sacrifice return in the long term, given their strong ethical premises.
2. The alternative or the *errors in expectations hypothesis* that suggests that the observed outperformance of SRI against the conventional one occurs because the social responsibility benefits and good performance factors are not already priced by investors.

In order to test these hypotheses, they formed two portfolios: one made with ethical or moral value criteria and another with the KLS sustainable responsibility factors by using data from 1992 to 2008 and the Carhart (1997) four-factor model to measure *alpha* or abnormal returns. Their tests found that the observed abnormal returns in the moral value KLS positive screening portfolio converged with the observed one in the moral value criteria. Their conclusions and results suggested that the error in expectations hypothesis holds in the short term and the shunned-stock one in the long term, a situation that is in line with Consolandi et al. (2008).

These two papers (Consolandi et al. and Derwall et al.) motivate the present one, mainly by the fact that we wanted to test if the inclusion or exclusion of stocks in the Mexican IPC sustainability index affects the performance of a stock, if the implementation of NPAP is priced by investors, and if it would have a positive and significant impact in the company's profits.

Departing from this and given the hypothesis in this paper in the previous section, we want to answer two closely related questions for the case of Mexican SRI: (1) Is SRI and the implementation of a NPAP priced by investors in the Mexican market? And (2) does the implementation of a NPAP have a positive impact on the profits of Mexican SRI companies?

Why did we want to test the impact of the implementation of NPAP either in the profits or in stock price performance? Because it is one of the most observable and notable activities in an environmental impact reduction program in a company and because the implementation of such programs requires notable human and financial resources from the company. A situation that presents two possible outcomes for the sponsoring company: (1) There could be a negative impact in the company's profits, or (2) there could be an "angel" affect that would lead to a better financial performance in the company.

If we found a statistical relation between the NPAP and the profits, the value of this impact could be the main NPAP indicator used to compare the benefits of such programs in other countries. We proposed this because the β_{NPAP} value of NPAP represents the contribution of a NPAP adoption in the rate of equity return.

Works such as the one of Martí-Ballester (2015) suggest that the implementation of cleaner production (i.e., the implementation of environmental programs) leads to a better financial performance in Spanish pension funds. Her results suggested that pension funds that invest in companies with cleaner production programs have a similar performance to the conventional ones, an issue that motivates our test of the influence of NPAPs in the profits of Mexican SRI companies.

The literature of SRI in Mexico is scant but precise. We can mention the works of Valencia (2015), De la Torre et al. (2016), and De la Torre and Martínez (2016) who tested the risk-adjusted return and the performance of the Mexican SRI against the conventional passive strategy. With different tests, they found that there was no loss of mean-variance efficiency if the investor used an SRI strategy against a conventional one, supporting the use of SRI in Mexico. In the case of De la Torre and Martínez (2016), their results were extended by testing the mean-variance efficiency in crisis (high volatility) periods and in normal (low volatility) ones. Their results gave proofs that SRI (IPC sustainability index) performed better in crisis periods than in conventional ones (IPC index).

Given this brief literature review, we found no previous work that measured impact in profits of environmental programs (more specifically, NPAPs) either worldwide or in Mexican public companies. The present paper is one of the first efforts in the subject. Departing from this, we will proceed to the empirical test of our hypothesis, followed by our proposal.

5.3 Empirical Test of the Impact of NPAP's in the Profits and SRI Stock Prices

5.3.1 Data Processing

In order to perform our test, we used the yearly historical data from 2014 to 2016 of the 33 stocks mentioned in Table 5.1.

To perform our test, we applied as regressors the 1-year $\beta_{i,\,t}$ of the i-th stock observed at the end of the year in the one-factor CAPM auxiliary regression:

$$\Delta\%P_{i,t} = \alpha_i + \beta_i \cdot \Delta\%IPC_t + \varepsilon_{i,t} \tag{5.1}$$

In the previous equation, $\Delta\ \%\ P_{i,\,t}$ and $\Delta\ \%\ IPC_t$ are the daily percentage variation of the price of the i-th stock and the Mexican IPC index, respectively. α is the inertial return or extra return from the market (IPC index) generated (on average) by the stock in the studied period (1 year), and β_i is the parameter of interest that measures the market exposure or systematic risk (Sharpe 1963). This parameter determines how much (in percentage units) the stock price increases or decreases with a given percentage unit increase or decrease in the market or IPC index. Finally, $\varepsilon_{i,\,t}$ is the percentage variation at t that is not explained by α,β, or $\Delta\ \%\ IPC_t$. The β_i in (5.1) tells how much market or systematic risk the i-th stock has leading to one of the most well-known models in finance. The capital asset pricing model or CAPM (Sharpe 1964) determines how much return $E(\Delta\ \%\ P_{i,\,t})$ is expected from the i-th stock, given its market influence or systematic risk measured with β_i, the expected return of a risk-free asset (rf) such as the return of the 28-day CETES in Mexico, and the expected return $E(\Delta\ \%\ IPC_t)$ in the market:

$$E\left(\Delta\%P_{i,t}\right) = rf + \left[\beta \cdot E\left(\Delta\%IPC_t\right) - rf\right] \tag{5.2}$$

We also used the values of market capitalization or market cap that measures the market value of the company's stocks traded in the equity market along with the entire year traded stock volume, the yearly stock price variation, and the return on investment (ROI) that we quantified as follows:

$$\text{ROI} = \frac{\text{Observed net profit during the year}}{\text{Net capital value at the end of the year}} \tag{5.3}$$

Table 5.1 Mean ROI values of the reviewed stocks that are or have been members of the IPCS index during the analysis

Company name	Stock ticker	Company name	Stock ticker	Company name	Stock ticker
Arca Contal S.A.B. De C.V.	AC*	*Grupo Elektra S.A.B. De C.V.*	ELEKTRA *	*Mexichem S.A.B. de C.V.*	MEXCHEM*
Grupo Aeromexico S.A.B. de C.V.	AEROMEX*	*Fomento Económico Mexicano S.A.B. de C.V.*	FEMSAUBD	*OHL México S.A.B. de C.V.*	OHLMEX*
Grupo Alfa S.A.B. de C.V.	ALFAA	*Gentera S.A.B. de C.V.*	GENTERA*	*Grupo Aeroportuario del Centro Norte S.A.B. de C.V.*	OMAB
Corporación ALSEA S.A.B. de C.V.	ALSEA*	*Grupo Financiero Banorte S.A.B. de C.V.*	GFNORTEO	*Industrias Peñoles S.A.B. De C.V.*	PE&OLES*
America Movil S.A.B de C.V.	AMXL	*Grupo Minero México S.A.B. De C.V.*	GMEXICOB	*Grupo Financiero Santander México S.A.B. de C.V.*	SANMEXB
Grupo Aeroportuario del Sur S.A.B. de C.V.	ASURB	*Grupo Herdez S.A.B. de C.V.*	HERDEZ *	*Organización Soriana S.A.B. de C.V.*	SORIANAB
Axtel S.A.B. De C.V.	AXTELCPO	*Infraestructura Energética Nova S.A.B. de C.V.*	IENOVA*	*Grupo Sports World S.A.B. de C.V.*	SPORTS
TV Azteca S.A.B. de C.V.	AZTECACPO	*Kimberly-Clark de México S.A.B: de C.V.*	KIMBERA	*Grupo Televisa S.A.B. de C.V.*	TLEVISACPO
Grupo Bimbo S.A.B. de C.V.	BIMBOA	*Coca-Cola Femsa S.A.B. de C.V.*	KOFL	*Corporación Inmobiliaria Vesta S.A.B. de C.V.*	VESTA*
Grupo Bolsa Mexicana de Valores S.A.B. de C.V.	BOLSAA	*Genoma-Lab S.A.B. de C.V.*	LABB	*Controladora Vuela Compañía de Aviación S.A.B. de C.V.*	VOLARA
Cementos Mexicanos S.A.B. de C.V.	CEMEXCPO	*Grupo Lala S.A.B. de C.V.*	LALAB	*Wal-Mart de México S.A.B. de C.V.*	WALMEX*

Table 5.2 The financial and market indicators used along with their units and EViews identifiers

Identifier	Description	Variable type	Units
BETA_IPC	The 1 year beta of a single-factor CAPM auxiliary regression of the i-th stock in a given year	Real number	Percentage expressed as real number: 1.00% = 1.00
NPAP	A dummy variable that verifies if the holding company of the i-th stock has an environmental protection program or not at a given year	Boolean (0,1)	Boolean (0,1)
IPCS	A dummy variable that verifies if the i-th stock is a member of the IPC sustainability index at a given year	Boolean (0,1)	Boolean (0,1)
MARKET_ CAP	The market capitalization or market cap value of the i-th stock at a given year	Real number	Mexican pesos expressed as real number: $1.00 = 1.00
ROI	The return on investment (ROI) of the i-th stock at a given year	Real number	Percentage expressed as real number: 1.00% = 1.00
VOLUME	The total volume of i-th stock at a given year in a given company	Real number	Units of traded stocks

Source: Own elaboration

A summary of the financial and market indicators used along with the units and identifiers (or codes) used in EViews for the test is presented in Table 5.2.

Our data was fetched from the Mexican Stock Exchange's databases through Economatica and is related to all the stocks that are or have been members of the Mexican IPC sustainability index during the test period. The key idea to test our hypothesis was to detect first if a relationship exists between the adoption of a NPAP either in the ROI (i.e., an angel effect) or in the stock price (i.e., NPAPs are priced by investors). We also wanted to test for endogeneity between the stock price variation $\Delta\ \%\ P_{i,\,t}$ and the ROI. For this purpose, we ran two separated regressions in a $T = 3 \times N = 33$ balanced panel with the pooled OLS method in (5.4) and (5.5).

$$\begin{aligned} \text{ROI} = \alpha + \beta_1 BETA\_IPC + \beta_2 ENV\_PROY + \beta_3 IPCS \\ + \beta_4 MARKET\_CAP + \beta_5 VAR\_P + \beta_6 VOLUME \end{aligned} \tag{5.4}$$

$$\begin{aligned} \text{VAR\_P} = \alpha + \beta_1 BETA\_IPC + \beta_2 ENV\_PROY + \beta_3 IPCS \\ + \beta_4 MARKET\_CAP + \beta_5 ROI + \beta_6 VOLUME \end{aligned} \tag{5.5}$$

Following each pooled OLS method, we tested for fixed effect across time or periods,[4] that is, that the α value was different for each stock in time ($\alpha_{i,\,t}$) and the

[4]We used the time fixed effects model for two reasons: (1) the number of years is 3, so the time series in each section or stock is small, leading to the next issue, and (2) there are 33 sections, and a 33 different values of α could lead to a non-feasible model in computational and mathematical terms.

β_i's were the same for all stock in every year. We made this test by following the conventional fixed effects F-statistic test:

$$F = \frac{\left(SSR_{\text{pooled\_OLS}} - SSR_{\text{fixed\_effects}}\right)/J}{SSR_{\text{fixed\_effects}}/\left(\left(N \cdot T\right) - K\right)} \tag{5.6}$$

In the previous expression, $T = 3$ is the number of time periods, $N = 33$ is the number of sections, $J = 3 - 2$ is the number of changing $\alpha_{i,t}'$s for each year minus one, $SSR_{\text{pooled\_OLS}}$ is the squared sum of residuals (SSR) of the pooled regressions given in (5.4) or (5.5), and $SSR_{\text{fixed\_effects}}$ is the corresponding SSR for the fixed effects regression version of (5.4) and (5.5). We didn't test for random effects due to the fact that we needed a number of years higher than the number of β_i's. We also did not run a fixed cross section (stocks) effects regression because we needed $N = 33 - 1 = 32$ changing $\alpha_{i,t}'$s or number years that we did not have in our database.

Once we had tested (5.4) and (5.5) for fixed effects and determined if we could use a pooled OLS or a fixed effects model, we eliminated the nonsignificant terms in the equation by following a backward (one-by-one) elimination process until all the remaining terms in the equation had a t-student probability equal or lower than 5%.

5.4 Tests Results Review

5.4.1 ROI Panel Regression

By following the steps mentioned in the previous section, we ran the first pooled regression given in (5.4) along with a fixed-time panel regression with the ROI as dependent variable. The results are presented in panels a and b of Table 5.3, respectively, and the result of the fixed effects F statistic given in panel c of the same table. As noted, the F right tail accumulated probability value of the F statistic of 0.3390 is 71.27%. According to the null hypothesis of this test (that there are no fixed effects and the α's in the pooled regression models are equal for all the years), we found no evidence to reject the use of the pooled OLS model. With this in mind, we ran the aforementioned backward elimination process, and we arrived at the final model given in Table 5.4.

As noted, practically all the regressors have been eliminated, and we found no evidence of endogeneity. That is, the percentage variation of the price ($\Delta\ \%\ P_{i,t}$ or VAR_P) was not part of the equation and did not explain the generation of the equity return (ROI). We also found that the market capitalization (MARKET_CAP) and the traded volume are significant but near zero, a situation that suggested that the implementation of a NPAP from among the selected regressors is the only one

Table 5.3 The results of the pooled OLS and fixed-time effects panel regressions with the ROI as dependent variable

Variable	Coefficient	Std. error	t-statistic	Prob.
Panel a. Pooled OLS regression				
BETA_IPC	−6.856463	6.965019	−0.984414	0.3275
ENV_PROY	13.97857	4.020561	3.47677	0.0008
IPCS	0.843257	7.36961	0.114424	0.9092
MARKET_CAP	3.27E-05	1.26E-05	2.599931	0.0109
VAR_P	0.05904	0.055318	1.067288	0.2886
VOLUME	−1.36E-09	7.96E-10	−1.707109	0.0912
α	3.225321	8.349235	0.386301	0.7002
R-squared	0.177923	*Mean dependent var*		9.504519
Adjusted R-squared	0.124309	*S.D. dependent var*		19.83014
S.E. of regression	18.55672	*Akaike info criterion*		8.747624
Sum squared resid	31680.38	*Schwarz criterion*		8.931117
Log likelihood	−426.0074	*Hannan-Quinn criter*		8.821866
F statistic	3.318609	*Durbin-Watson stat*		0.464289
Prob(F statistic)	0.005291			
Panel b. Fixed (time) effects panel regression				
BETA_IPC	−7.765049	7.111346	−1.091924	0.2778
ENV_PROY	14.24759	4.064098	3.50572	0.0007
IPCS	3.426647	8.11024	0.422509	0.6737
MARKET_CAP	3.22E-05	1.27E-05	2.535603	0.013
VAR_P	0.0655	0.056367	1.162018	0.2483
VOLUME	−1.32E-09	8.03E-10	−1.64383	0.1037
α	1.424748	8.708947	0.163596	0.8704
R-squared	0.184087	*Mean dependent var*		9.504519
Adjusted R-squared	0.111561	*S.D. dependent var*		19.83014
S.E. of regression	18.6913	*Akaike info criterion*		8.780502
Sum squared resid	31442.84	*Schwarz criterion*		9.016422
Log likelihood	−425.6348	*Hannan-Quinn criter*		8.875956
F statistic	2.538233	*Durbin-Watson stat*		0.456921
Prob(F statistic)	0.015377			
Panel c. Fixed effects F test				
Effects test		***Statistic***	***d.f.***	***Prob.***
Period F		0.339961	(2,90)	0.7127

Source: Own elaboration with data from the Mexican stock exchange and Economatica

that explains the return generation in the studied companies (as theoretically expected). Table 5.4 suggests that from the selected companies, the implementation of NPAP added, on average, 13.38% of equity return or ROI. So, it is expected, in the Mexican case and in the studied stocks, that the implementation of a NPAP could lead to an "angel" effect that gives more profits to the company, thanks to the implementation of several environmental impact policies such as a NPAP.

Table 5.4 The final pooled OLS regression model for the ROI

Variable	Coefficient	Std. error	t-Statistic	Prob.
ENV_PROY	13.38839	2.883603	4.642938	0
MARKET_CAP	3.12E-05	1.09E-05	2.867133	0.0051
VOLUME	−1.58E-09	7.42E-10	−2.136085	0.0352
R-squared	0.153349	*Mean dependent var*		9.504519
Adjusted R-squared	0.135711	*S.D. dependent var*		19.83014
S.E. of regression	18.43552	*Akaike info criterion*		8.69627
Sum squared resid	32627.38	*Schwarz criterion*		8.77491
Log likelihood	−427.4654	*Hannan-Quinn criter*		8.728088
Durbin-Watson stat	0.525964			

Source: Own elaboration with data from the Mexican Stock Exchange and Economatica

5.5 Percentage Stock Price Variation or VAR_P Panel Regression Model

Following the ROI regression model, we followed the same steps by using the percentage variation of the price of the i-th stock with (5.5) as starting point. The results of the pooled regression, the fixed-time effects, and the fixed effects test are shown in panels a, b, and c of Table 5.5, respectively. As in the case of the ROI model, we found no evidence in favor of the fixed effects panel regression, so we used the pooled OLS model. After this result, we applied the same backwards elimination process and arrived at the list of regressors shown in Table 5.6. As noted, our results show (in both models) that there is no endogeneity between (5.4) and (5.5) with the ROI outside the VAR_P equation and vice versa.

We also found that the results were practically similar to the theoretical expected functional form of a CAPM model. These results also answered our first particular question stated in the literature review: Is SRI priced by investors in the Mexican stocks that are members of the IPC index? The observed answer is that neither SRI nor the adoption of a NPAP is priced by investors in the Mexican case. Another issue of interest is the fact that for these stocks in a balanced panel regression, the sign of the beta value was negative (contrary to the expected positive value), leaving this issue for further research.

5.6 Corollary of Results

The main findings that we found in our test are that neither the ROI nor the percentage variation shows endogeneity. In other words, the percentage variation of the stock price is not a regressor or factor that explains the ROI in a company nor is the ROI a factor that determines the price of a SRI stock. Finally, only the adoption of a NPAP by a company (among the selected factors in our test) gives an explanation for ROI generation, answering our second question and giving proofs of the benefits of implementing environmental impact plans such as NPAP in a company.

Table 5.5 The results of the pooled OLS and fixed-time effects panel regressions with the percentage price variation (VAR_P) as dependent variable

Variable	Coefficient	Std. error	t-statistic	Prob.
Panel a. Pooled OLS regression				
BETA_IPC	−21.62284	9.83323	−2.198956	0.0294
ENV_PROY	0.894378	5.823993	0.153568	0.8782
IPCS	−1.850227	8.759365	−0.211228	0.833
MARKET_CAP	7.77E-06	1.80E-05	0.432036	0.6663
ROI	0.320307	0.160418	1.9967	0.0476
VOLUME	2.15E-10	1.11E-09	0.193776	0.8466
α	22.35936	10.24726	2.181985	0.0306
R-squared	0.063369	Mean dependent var		8.778281
Adjusted R-squared	0.026877	S.D. dependent var		34.58601
S.E. of regression	34.11806	Akaike info criterion		9.940035
Sum squared resid	179262.5	Schwarz criterion		10.07401
Log likelihood	−793.1729	Hannan-Quinn criter		9.994434
F statistic	1.736511	Durbin-Watson stat		2.323075
Prob(F statistic)	0.116027			
Panel b. Fixed (time) effects panel regression				
BETA_IPC	−19.80814	10.05279	−1.970412	0.0506
ENV_PROY	0.452364	5.915638	0.076469	0.9391
IPCS	−5.077366	9.341063	−0.543553	0.5876
MARKET_CAP	7.74E-06	1.83E-05	0.423181	0.6728
ROI	0.333409	0.164278	2.029538	0.0442
VOLUME	2.06E-10	1.13E-09	0.182287	0.8556
α	23.81374	10.434	2.282321	0.0239
R-squared	0.072815	Mean dependent var		8.778281
Adjusted R-squared	0.011003	S.D. dependent var		34.58601
S.E. of regression	34.39521	Akaike info criterion		9.979588
Sum squared resid	177454.5	Schwarz criterion		10.19012
Log likelihood	−792.3569	Hannan-Quinn criter		10.06507
F statistic	1.178005	Durbin-Watson stat		2.324869
Prob(F statistic)	0.30995			
Panel c. Fixed effects F test				
Effects test		*Statistic*	*d.f.*	*Prob.*
Period F		1.172377	(2,90)	0.3143

Source: Own elaboration with data from the Mexican Stock Exchange and Economatica

5.7 Conclusions

Socially responsible investment (SRI) is an investment style that has gained more popularity since the 1970s when it was used as an activist measure against companies considered "unethical," such as the ones that produced weapons, army technology, alcohol, gambling, and alike. Since then, this type of investment has grown in

Table 5.6 The final pooled OLS regression model for the ROI

Variable	Coefficient	Std. error	t-statistic	Prob.
BETA_IPC	−22.06541	11.13141	−1.982265	0.0503
α	26.2213	9.814259	2.671756	0.0089
R-squared	0.038932	Mean dependent var		8.023271
Adjusted R-squared	0.029024	S.D. dependent var		35.03622
S.E. Of regression	34.52403	Akaike info criterion		9.941183
Sum squared resid	115615.1	Schwarz criterion		9.99361
Log likelihood	−490.0886	Hannan-Quinn criter.		9.962395
F statistic	3.929374	Durbin-Watson stat		2.983749
Prob(F statistic)	0.050279			

Source: Own elaboration with data from the Mexican Stock Exchange and Economatica

traded volume and is part of the asset allocation step in portfolios of institutional investors such as banks, pension funds, or insurance companies. The aim of this paper is not to talk in detail about this subject but to test if the implementation of environmental programs, such as the adoption of Natural Protected Areas Programs (NPAP), has a positive impact in the performance of Mexican Public companies, either in the stock price or in the financial benefits (measured through the return on investment or ROI). For this purpose we used yearly historical data from 2014 to 2016 of 33 Mexican stocks that are or have been members of the IPC sustainability index, published by Standard and Poor's and the Mexican Stock Exchange. Among the data fields that we used are the yearly percentage price variation of each stock, the observed 1-year beta or systematic risk measure, the ROI observed in the 12 months of each year, the market capitalization at the end of the year, the total traded volume of each stock during the year, and the two binary variables that determine if the i-th stock is socially responsible at t (a stock member of the IPC sustainability index) or if it has a NPAP. By running a balanced panel with a pooled regression model in two regressions (one for the price percentage variation and another for the ROI as dependent variables), we found that the percentage variation and the ROI showed no endogeneity and that the quality of being socially responsible and the implementation of a NPAP have no impact in the yearly price percentage variation. That is, SRI is not priced by investors in the case of the Mexican Stock Exchange.

In the ROI panel regression model, we found that the implementation of a NPAP increase the ROI in a 13.38% on average, suggesting that even though SRI is not priced by investors, the implementation of environmental programs such as NPAP has a financial benefit for the company and its stakeholders such as investors.

This last result leads us to suggest the implementation of panel regression models in several countries to test if this relation holds and if so, to suggest that the β_{NPAP} value should be interpreted as the contribution to the equity return in the given country. If this contribution is higher, it is because of the implementation of environmental programs, such as NPAPs, and the company's profits have a harmonic relation, and, as a consequence, not only the company but the country is more SRI in environmental terms.

As extensions of this paper and guidelines for further research, we find it necessary to extend this test to a wider period in Mexico or to perform this test in a quarterly or even monthly basis. The application of our study in other countries could also be of interest along with the application of other econometric techniques and the comparison of the β_{NPAP}values as a potential benefits indicator of the implementation of Natural Protected Areas Programs (NPAP's) in a given country.

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Chapter 6
Intellectual Property and the Governance of Plant Genetic Resources in Mexico: Trends and Implications for Research and Innovation

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Abstract This chapter explores how the regulation of plant genetic resources intersects with legal regimes granting intellectual property rights in Mexico. Our analysis is directed towards addressing the argument that regimes governing access to plant genetic resources and the sharing of benefits derived from their commercial exploitation could discourage research and innovation in fields that rely on such resources as inputs. To engage with this critique, we examine the relationship between plant genetic resources and intellectual property, because trends in intellectual property protection may elucidate research and innovation dynamics. Our findings surrounding applications for patents and plant breeders' rights in Mexico indicate that intellectual property activity related to plant genetic resources can intensify even as new frameworks for the governance of these resources are designed and popularized. However, it is important to note that it is still unknown whether the implementation of a national regime based on the Nagoya Protocol in Mexico might impact the activities of users and providers of genetic resources, including in relation to intellectual property protection.

Keywords Plant genetic resources · Intellectual property · Nagoya Protocol · Access and benefit sharing · Mexican native plants

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6.1 Introduction

Plant genetic resources are highly valuable, providing the foundation for knowledge development in a variety of scientific fields as well as the basis for important commercial products. At a more primordial level, these resources have intrinsic value related to the role that they play in both natural ecosystems and traditional communities. In recent years, several landmark international legal instruments have been developed to structure transactions centring on plant genetic resources. Such regimes attempt to consider the interests of a variety of stakeholders surrounding the uses of particular plants, as well as the knowledge or information associated with these resources.

The first and most prominent international framework for the governance of plant genetic resources is the Convention on Biological Diversity (CBD 1992), which entered into force in 1993. The CBD acknowledges that individual States have sovereign rights to regulate biological resources sourced from within their borders, as well as to stipulate how any benefits that users perceive from the exploitation of these resources should be shared with providers (Article 15.1 and 15.7). More recently, the Nagoya Protocol, a supplementary agreement to the CBD, established a comprehensive framework to regulate access to genetic resources and equitable benefit sharing between users and providers.[1]

As the international landscape for the governance of plant genetic resources has evolved, so too has the debate over how to regulate access and benefit sharing at the national level. It has been broadly acknowledged that the Nagoya Protocol did not fully address many stakeholders' concerns, and indeed the agreement requires national action to implement its substantive obligations (Nijar 2011). To date, few countries have enacted comprehensive access and benefit-sharing frameworks, though at the time of writing, the Nagoya Protocol had 100 members (CBD 2018). Nevertheless, some States are now beginning to implement national laws to give effect to the provisions of the Protocol. Thus, there exists a need to better understand how both users and providers of plant genetic resources might be impacted by these new regimes.

In the present chapter, we focus on elucidating how the regulation of plant genetic resources intersects with legal regimes granting intellectual property rights in Mexico. Our analysis is directed towards addressing the argument that regimes governing access to plant genetic resources and the sharing of benefits derived from their commercial exploitation could discourage research and innovation in fields

[1] Another international instrument that covers issues related to the governance of genetic resources is the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), which entered into force in 2004. The ITPGRFA is designed to recognize the enormous contribution of farmers to crop genetic diversity; create a global system to provide farmers, plant breeders, and scientists with access to plant genetic materials; and ensure that recipients share benefits that they derive from the use of genetic materials with the countries where they originated. While the ITPGRFA is a highly relevant treaty to the global governance of plant genetic resources, it is not covered in this chapter because at the time of writing, Mexico was not a contracting party.

that rely on such resources as inputs (e.g. Jinnah and Jungcurt 2009). In order to engage with this general critique, we examine the relationship between plant genetic resources and intellectual property.

The rationale for this focus is that trends in intellectual property protection may elucidate research and innovation dynamics. For instance, in some instances exclusive intellectual property rights may deter both upstream research and downstream product development (e.g. Heller and Eisenberg 1998), potentially affecting the institutional cultures of universities and public research centres (Lei et al. 2009). Yet at the same time, intellectual property in the form of patents or plant breeders' rights might act as indicators for the economic valuation of plant genetic resources (Lee and Sohn 2016), thereby facilitating negotiations towards benefit-sharing agreements by mitigating information asymmetries between users and providers (Nelliyat 2017). Thus, regimes regulating access to and intellectual property protection of plant genetic resources intersect in numerous ways, which in many instances remain to be researched.

The present chapter is structured as follows: in Sect. 6.2 we review the relevant national legal frameworks in Mexico. These include the emerging national system for the governance of genetic resources based on the Nagoya Protocol, as well as the country's laws granting intellectual property protection through patents and plant breeders' rights. Subsequently, we present data related to filings for plant breeders' rights and patents, both in Mexico and internationally, in relation to ten particular species of Mexican native plants. Our conclusions centre on the interrelationship between intellectual property and plant genetic resources in the Mexican context, focusing on implications for future research and innovation.

6.2 Legal Frameworks for the Regulation of Plant Genetic Resources in Mexico

Mexico is classified as one of the 17 "megadiverse" countries in the world, meaning that it belongs to a group of nations that house the majority of all species on Earth, in addition to having a large volume of endemic species (Mittermeier et al. 1997). The country is both a provider and a user of genetic resources, and Mexico is also home to numerous indigenous communities, which collectively represent nearly 10% of the total national population (CDI 2006). These communities possess important reserves of traditional knowledge surrounding the use of plant genetic resources, which in many instances would likely form part of the subject matter of access and benefit-sharing agreements. Given this national profile, it is perhaps unsurprising that Mexico was a major proponent of the Nagoya Protocol, which it signed in February 2011.

Although Mexico was the sixth country in the world to adhere to the Nagoya Protocol, the country still does not have a comprehensive, binding national law that would implement the Protocol. Instead, Mexico has outlined a series of actions as part of its National Strategy on Biodiversity ("ENBioMex") 2016–2030. This guidance document establishes a set of key elements for the sustainable conservation, restauration, and management of Mexican biodiversity. Furthermore, the ENBioMex plan is based on 14 governing principles along 6 strategic axes, which include (1) knowledge governance; (2) conservation and restauration; (3) sustainable use and management; (4) prevention and control; (5) environmental education, communication, and culture; and (6) integration and governance (ENBioMex 2016). Although the National Strategy on Biodiversity is nonbinding, it is ambitious in scope and demonstrates the commitment of the Mexican federal government to substantiate the aspirations of the CBD and Nagoya Protocol through domestic legislation.

More recently, in October 2017 a new policy entered into force under the jurisdiction of the Mexican Secretary of Agriculture (SAGARPA), which acts as an interim mechanism for the review of applications for access to plant genetic resources for food and agriculture. This policy is legally binding, and it establishes the steps that SAGARPA and the National Service for Seed Inspection and Certification (SNICS) must follow to evaluate permit applications to access plant genetic resources for uses in the food and agricultural contexts. The document is intended to serve as a transitional measure until a comprehensive national framework to implement the Nagoya Protocol is enacted.

The SAGARPA policy outlines procedures for the submission and evaluation of permit applications for access to plant genetic resources, the emission of permitting decisions by the Mexican federal government, how to deal with commercial uses of plant genetic resources, and guidelines for how to negotiate and execute benefit-sharing agreements with genetic resource providers (SAGARPA & SNICS 2017). Furthermore, as part of the interim policy and in order to facilitate negotiations between providers and users, the Secretary of Agriculture has published template agreements for prior informed consent and equitable benefit sharing.

While the national framework for the governance of plant genetic resources continues to evolve in Mexico, the country has firmly established intellectual property laws. Although the country offers a variety of mechanisms to protect intellectual property rights, the systems that are most relevant to plant genetic resources are plant breeders' rights and patents (e.g. Raustiala and Victor 2004). The former system confers exclusive yet temporary rights to the developers of new varieties of plants (i.e. breeders) in relation to the commercial use of these varieties. Plant breeders' rights laws interrelate with regimes governing genetic resources where breeding material sourced from native or local plants is used to develop new, commercially viable varieties. Meanwhile, patents are a form of intellectual property designed to reward the creators of novel, inventive, and useful products and processes. Plant genetic resources provide important inputs to a wide array of patentable subject matter, including research tools used to develop genetically modified organisms, biofuels, medications, and cosmetics, among many other types of products.

The Mexican system for plant breeders' rights is based on the 1978 version of the Convention of the International Union for the Protection of New Varieties of Plants (UPOV 1978), to which Mexico adhered in 1997. The prior year, the Federal Law on Plant Varieties was enacted, and this legislation was subsequently reformed in

2012. The Federal Law on Plant Varieties grants plant breeders the right to utilize and exploit – for a period of 15–18 years, depending on the species – plant varieties and associated propagating material, in relation to the production, reproduction, distribution, and sale thereof (LFVV 1996).

Meanwhile, the system for patent protection in Mexico dates to 1942 when the country's first Patent and Trademark Law was enacted. This regime was reformed in 1991 to become a comprehensive Industrial Property Law (Ley de Propiedad Industrial 1991), at which time the Mexican Intellectual Property Institute (IMPI) was created to review applications for patents and other forms of intellectual property. The Industrial Property Law has been reformed several times since 1991, most recently in 2012. These newer iterations of the Mexican Industrial Property Law have gradually expanded the scope of patentable subject matter. Until 1994, several classes of inventions related to plant genetic resources were not considered patentable, including biotechnological processes; medications in general; animal feed; fertilizers, pesticides, herbicides, and fungicides with biological activity; genetic processes to obtain plant or animal species; and plant varieties and animal breeds (Carrasco 2012).

The 1994 reform to the Industrial Property Law eliminated several of these restrictions. As a result, classes of products including biotechnological processes, medications, and agricultural inputs such as fertilizers and pesticides are now patentable. Yet even today many types of inventions related to the use of plant genetic resources are excluded from patent protection. For instance, non-patentable subject matter in the current (2012) version of the Mexican Industrial Property Law includes essentially biological processes for the production, reproduction, and propagation of plants and animals; biological and genetic material as found in nature; animal breeds; and plant varieties (LPI, Article 16).

One general feature of the Mexican intellectual property system is that the plant breeders' rights and patent laws do not permit the granting of exclusive rights over naturally occurring plant genetic resources. Nevertheless, these regimes do allow for intellectual property rights to be obtained for derivatives of such resources, such as improved plant varieties using native or local plants as parental lines (plant breeders' rights) or compositions made from plant materials (patents). In the following section, we examine how these regimes have operated in practice to grant intellectual property rights over subject matter derived from ten native Mexican plant species. We also review how these same species have been protected with intellectual property internationally.

6.3 Trends Related to the Protection of Mexican Plant Genetic Resources with Intellectual Property

Since the 1980s, intellectual property protection in the form of plant breeders' rights and patents has become increasingly important for scientific research on plant genetic resources, as well as for the utilization and commercialization of research results. This trend is evidenced in changes to patentability requirements in multiple territories to permit the protection of living forms, the execution of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) in 1995, and the subsequent burgeoning of UPOV membership (Correa 1995). The negotiation and execution of the CBD and the Nagoya Protocol have occurred concurrent with these developments. Today, laws providing for the protection of plant genetic resources with intellectual property interrelate with access and benefit-sharing regimes in multiple ways.

Below, we demonstrate how the plant breeders' rights and patent regimes are increasingly utilized in Mexico and internationally to protect subject matter derived from Mexican plant genetic resources. We particularly focus on instances in which rights have been granted in relation to ten native Mexican plant species. The species that we selected are *Agave tequilana* (blue agave), *Gossypium hirsutum* (cotton), *Opuntia ficus-indica* (nopal), *Physalis ixocarpa* (husk tomato), *Simmondsia chinensis* (jojoba), *Sechium edule* (chayote), *Solanum lycopersicum* (tomato), *Theobroma cacao* (cacao), *Turnera diffusa* (damiana), and *Zea mays* (maize or corn).

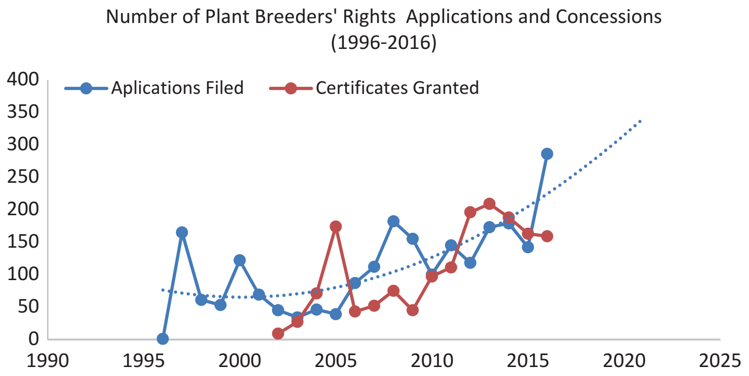
We chose these particular species for several reasons. All are considered to be native to Mesoamerica, a region that today partially falls within the borders of Mexico. The selection represents a range of plant types covering a variety of uses, including the generation of numerous agricultural, chemical, food, textile, and pharmaceutical products. Finally, we intentionally selected plant species that are both popularly cultivated throughout the world and those which are relatively unknown outside of Mexico, in order to highlight different issues related to the intersection between intellectual property laws and regimes governing access to genetic resources.

6.3.1 Protection via Plant Breeders' Rights

Since the Federal Law on Plant Varieties was enacted in 1996, the number of applications filed for plant breeders' rights in Mexico has steadily increased. This trend is illustrated in Fig. 6.1.

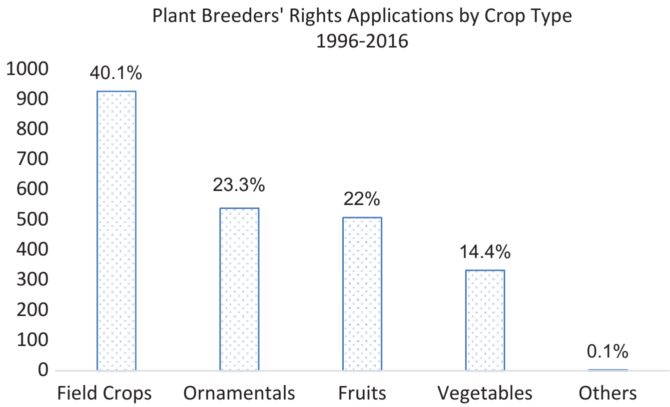
Figure 6.1 demonstrates increases in both plant breeders' rights applications and granted breeders' rights certificates during the period of 1996–2016. The total number of applications reached 2314 by 2016 and covered 123 crop species. Meanwhile, of the total number of applications, as of 2016 1619 breeders' rights certificates had been granted. Of the total number of granted certificates, 84.3% were active at the time of writing, highlighting the increase in activity in recent years.

The number of plant breeders' rights applications by type of crop can be seen in Fig. 6.2. Clearly, domestic Mexican and international institutions and firms were most interested in obtaining protection for plant varieties that are cultivated as large-scale commercial field crops. Meanwhile, nearly equal proportions of applications claimed fruit and ornamental varieties, while relatively less activity was associated with the registration of vegetable varieties.



Source: Authors' elaboration based on data from the Official Plant Breeders' Rights Gazette from SAGARPA.

Fig. 6.1 Number of plant breeders' rights applications and concessions (1996–2016). (Source: Authors' elaboration based on data from the official plant breeders' rights gazette from SAGARPA)



Source: Authors' elaboration based on data from the Official Plant Breeders' Rights Gazette from SAGARPA.

Fig. 6.2 Plant breeders' rights applications by crop type 1996–2016. (Source: Authors' elaboration based on data from the official plant breeders' rights gazette from SAGARPA)

Within these broad categories of crop type are several plant species that would likely be understood as Mexican plant genetic resources under the terms of the forthcoming national access and benefit-sharing regime, due to their common designation as native crops and the fact that they are likely to be sourced in Mexico. For instance, in recent years applications have been filed for varieties of crops that are popularly cultivated worldwide, some species of which were domesticated in Mexico. These include varieties of grains, pulses, tubers, and fibre crops such as amaranth, beans, cotton, maize, potato, and sorghum, as well as fruit and vegetable crops such as avocado, cacao, chili pepper, papaya, and tomato. Plant breeders' rights have also been sought for varieties of relatively less common food and ornamental plants that were domesticated in Mexico, including agave, chayote, chia, dahlia, husk tomato, and nopal, among others (SNICS 2016).

The ten species of interest for the present analysis have interacted with the plant breeders' rights system in Mexico in diverse ways. Perhaps unsurprisingly given the global importance of maize as an important source of food, feed, and fuel, more breeders' rights applications were lodged in Mexico for *Zea mays* than for any other plant species. Specifically, as of 2016, a total of 422 applications had been filed, representing 19% of all breeders' rights applications from 1996 to 2016 (SNICS 2016). Similarly, *Gossypium hirsutum* (cotton) appeared in seventh place for the total number of applications from 1996 to 2016, with 68 filings or 3% of the total. A relatively high amount of activity also surrounded *Solanum lycopersicum* (tomato), with 42 applications lodged over the 20-year period, for approximately 2% of the total.

Meanwhile, far fewer applications had been filed to claim rights over new varieties of the other species of interest. Ten applications were filed to claim new varieties of *Physalis ixocarpa* (husk tomato; 0.44% of the total), while five applications were filed for *Opuntia ficus-indica* (nopal; 0.22% of the total). Other species were even less likely to be protected with breeders' rights in Mexico. Four applications were filed from 1996 to 2016 for *Sechium edule* (chayote; 0.2% of the total), and only one application was filed for a variety of *Theobroma cacao* (cacao; 0.04% of the total). No applications were filed in Mexico for varieties of *Agave tequilana* (blue agave), *Simmondsia chinensis* (jojoba), or *Turnera diffusa* (damiana).

While these findings illustrate the commercial value of native species within Mexico, it is important to note that the Nagoya Protocol was primarily designed to address concerns over international rather than national uses of plant genetic resources (Kamau et al. 2010). For this reason, it is important to examine instances in which rights have been granted over the ten Mexican native species of interest in other territories. In order to gather these data, we conducted searches in the PLUTO Plant Variety Database, which is administered by UPOV. We conducted searches by botanical name for the ten species of interest and discovered that in many cases, plant breeders' rights have been granted for new varieties of these species.

Unsurprisingly, an enormous volume of plant breeders' rights applications has been filed for varieties of *Zea mays* (maize). Including hybrid varieties, 119,016 filings were located for maize in the PLUTO database, in dozens of territories throughout the world. A large number of breeders' rights applications have also been lodged for *Gossypium hirsutum* (cotton; 3401), likewise in numerous countries. Significant activity also surrounded *Solanum lycopersicum* (tomato), with a total of 961 applications filed in 14 countries.

The remaining seven plant species were less commonly protected with plant breeders' rights. We located 29 filings through the PLUTO database covering *Theobroma cacao* (cacao), which were lodged in four countries. For *Physalis ixocarpa* (husk tomato), we found 28 applications in four countries, while 20 filings were encountered in relation to *Opuntia ficus-indica* (nopal), in three territories. Eleven applications had been filed for *Simmondsia chinensis* (jojoba) in three countries, while for *Sechium edule* (chayote), the only filings that appeared in the PLUTO database were made in Mexico (4). Finally, no records were found for *Agave tequilana* (agave) or *Turnera diffusa* (damiana).

The results demonstrate that in many instances, Mexican native plant species have been protected with plant breeders' rights, both in Mexico and in other territories. These data illustrate the fact that plant varieties derived from Mexican plant genetic resources may have commercial value in numerous world regions. In the future, if germplasm is obtained from within Mexico, whether in situ or from ex situ collections, the emerging legal framework for plant genetic resources governance will be implicated.

6.3.2 Protection via Patents

To elucidate the interrelationship between patenting and issues surrounding access to plant genetic resources in Mexico, we searched for patent documents published by the Mexican Intellectual Property Institute that included claims covering the ten plant species described above. Our searches were limited to patent applications and granted patents published since 1993, the date on which the CBD entered into force.

As demonstrated in Table 6.1, multiple patent applications have been filed since 1993 claiming the ten plant species of interest, and many of these applications have also resulted in granted patents. Meanwhile, Fig. 6.3 displays the number of patent applications filed by species, illustrating the fact that in general, the number of applications filed in relation to the ten species of interest has increased noticeably beginning in 2012. Figure 6.4 presents the number of granted patents by species since 1993. In comparison to the number of patent applications filed, relatively few patents have been granted for the ten species of interest since 2012. However, it is likely that their corresponding applications are still undergoing prosecution in the Mexican Intellectual Property Institute, and as such it is likely that the number of patents granted in relation to these five species will increase in the near future.

The overall trends in patenting activity in Mexico surrounding the ten species of interest are demonstrated in Fig. 6.5. This graph reveals a general increase in the number of patent applications with claims covering these species since 1993. Patenting activity has increased steadily over this period, and it is notable that the filing of patent applications appears to not have been negatively impacted by Mexico's signing of the Nagoya Protocol in 2014. In other words, these data suggest that to date, the country's adherence to the Nagoya Protocol has not impacted patenting activity in Mexico, in relation to Mexican plant genetic resources. Such a finding is not necessarily surprising, given that the interim permitting policy for access to plant genetic resources for uses in the food and agricultural contexts – the first legally binding framework in Mexico to cover such subject matter – was only enacted in October 2017. It remains to be seen whether this new regime might affect patenting activity in the future.

Table 6.1 Patenting trends for Mexican native plants in Mexico

		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Simmondsia chinensis	PA	–	–	–	–	3	1	1	1	2	2	3		1	2	3		1	–	1	2	1	2	6	1	1
	GP	2	–	–	1	–	–	1	–	1	–	1	–	–	–	–	–	1	–	1	1	–	–	–	–	–
Sechium edule	PA	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	2	2	1	–	–	–
	GP	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–
Agave tequilana	PA	–	2	1	–	–	–	–	–	2	3	3	1	2	–	–	1	4	4	4	2	7	3	3	6	1
	GP	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–	1	–	–	–	–	–
Zea mays	PA	–	–	–	–	–	2	5	6	14	10	6	7	6	5	10	7	8	12	11	12	14	6	9	20	5
	GP	1	1	–	2	1	1	2	3	4	3	4	4	7	2	7	5	4	7	4	7	6	2	–	–	–
Turnera diffusa	PA	1	–	–	–	–	–	–	1	1	–	–	–	–	1		3	1	1	–	–	1	2	2	1	–
	GP	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
Gossypium hirsutum	PA	–	–	–	–	–	–	1	1	1	2	–	1	–	2	3	2	2	3	2	5	3	5	3	6	-
	GP	–	–	–	–	–	–	-	1	1	–	–	–	–	–	1	2	-	2	1	4	1	1	–	–	–
Opuntia ficus-indica	PA	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	2	2	1	2	5	5	6	2	–	–
	GP	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	–	2	2	–	–	–	–
Physalis ixocarpa	PA	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	–	–	–	–
	GP	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–
Theobroma cacao	PA	–	–	–	–	–	1	–	–	1	-	1	1	1	2	2	2	–	5	2	4	1	7	3	2	2
	GP	–	–	–	–	–		–	–	1	–	–	–	–	–	–	1	–	1	-	3	-	-	–	-	-
Solanum lycopersicum	PA	–	–	–	–	–	1	2	1	–	–	–	–	1	1	1	3	3	5	8	6	2	9	7	3	6
	GP	–	–	–	–	–		1	1	–	–	–	–		1	1	2	1	3	3	3	–	–	–	–	–

Source: Authors' elaboration based on data from the Official SIGA database of the Mexican Intellectual Property Institute (IMPI)
PA patent application, *GP* granted patent

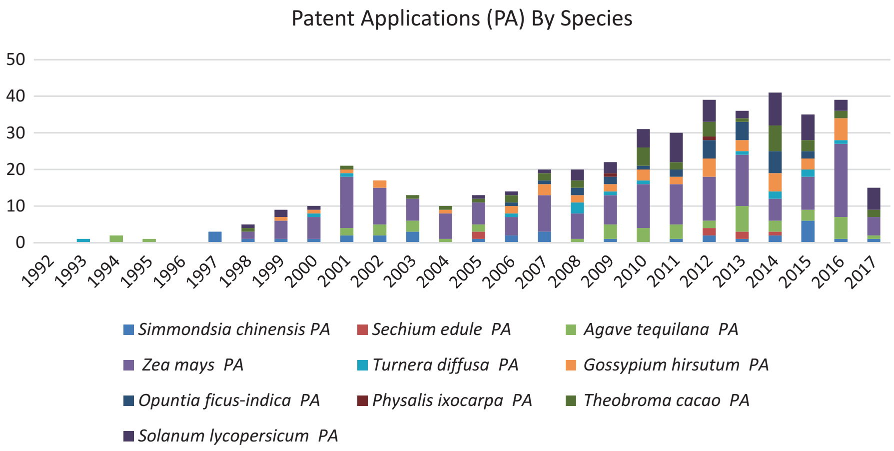


Fig. 6.3 Patent applications (PA) by species

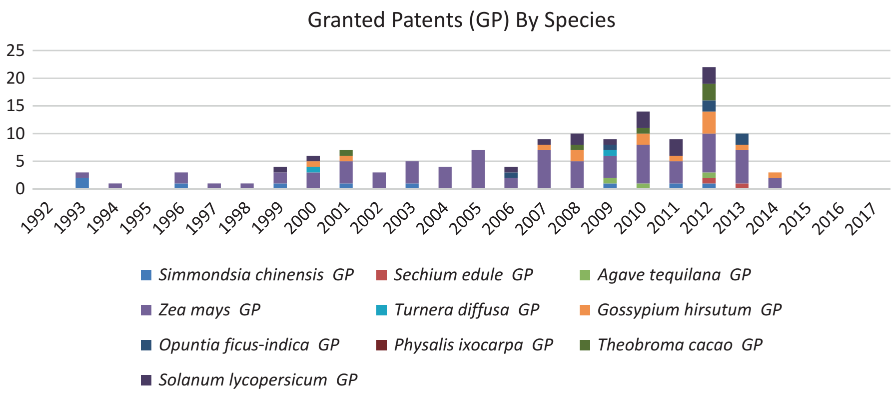


Fig. 6.4 Granted patents (GP) by species

To gain a broader understanding of the relevance of intellectual property protection to Mexican plant genetic resources, we decided to delve more deeply into international patent filings related to three of the ten species of interest. We selected *Turnera diffusa, Agave tequilana,* and *Sechium edule* for further analysis. Our selection was based on the fact that these plants are less widely known internationally than other Mexican plants such as *Zea mays* or *Gossypium hirsutum*, and because these three species have seldom been protected with plant breeders' rights, as discussed above.

The common name of *Turnera diffusa* is damiana. This plant is a diminutive, woody shrub that produces small, aromatic flowers. Damiana is native to southern Texas in the United States, parts of Central America, South America, and the

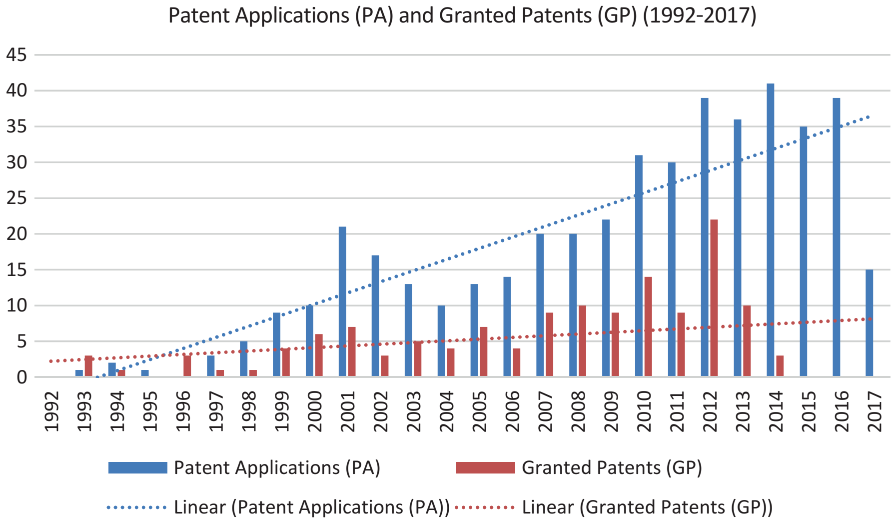


Fig. 6.5 Patent applications (PA) and granted patents (GP) (1992–2017)

Caribbean, and arid regions of Mexico. *Turnera diffusa* has been used in numerous commercial products since at least the nineteenth century, especially in the food and pharmaceutical industries. The essential oils derived from Damiana have been reported to have stimulant, diuretic, and aphrodisiac effects, among others (Martín-Martínez 2013).

As discussed above, searches conducted in the database of the Mexican Intellectual Property Institute revealed only five patent applications and zero granted patents claiming products or processes related to *Turnera diffusa*, for the period of 1993–2017. However, searches in the international patent database administered by Derwent Innovation® encountered a significantly larger number of records. Specifically, 131 patent documents were found in 55 patent families covering compositions used to stimulate weight loss, produce food products, and treat a variety of medical disorders. The territories with the greatest number of patent families related to *Turnera diffusa* were the United States (ten families), Canada (six families), Australia (four families), Morocco (four families), Japan (three families), Germany (three families), European Patent Office (two families), Mexico (two families), and South Korea (two families) (Fig. 6.6). Patenting activity related to *Turnera diffusa* appears to have remained relatively consistent over time, while the greatest number of documents was published in 2016 (Fig. 6.7).

Similar results were found in relation to *Agave tequilana*. This plant is commonly known as blue agave or tequila agave, and its most widespread commercial application has been in the form of the distilled, alcoholic beverage tequila. The high production of sugars, mainly fructose, in the core of the blue agave plant renders it useful for tequila production, as well as for food and other products, including paper (Iñiguez-Covarrubias et al. 2001).

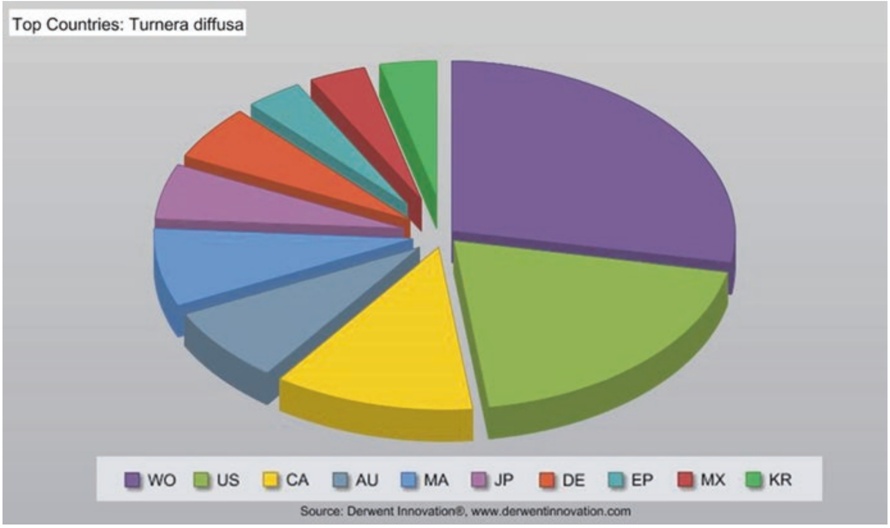


Fig. 6.6 *Turnera diffusa* countries

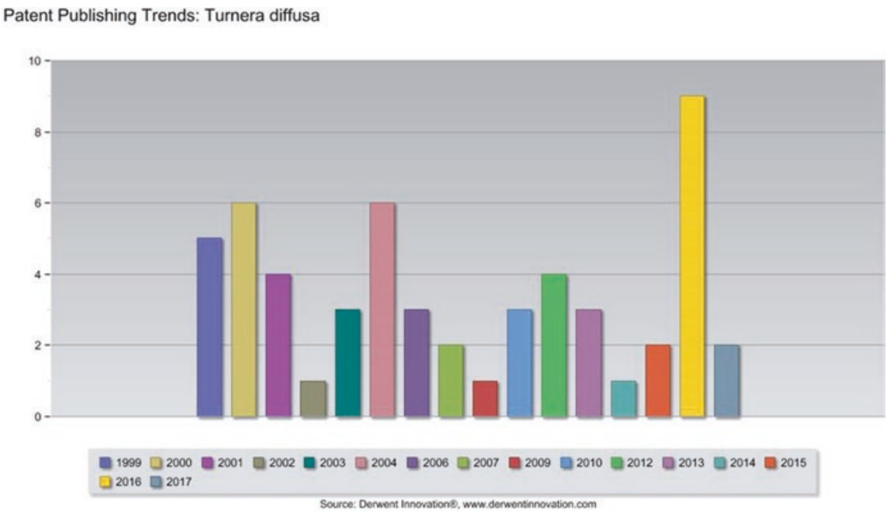


Fig. 6.7 *Turnera diffusa* patenting trends

At the international level, 57 patent documents were located in 38 families with claims covering *Agave tequilana* (Fig. 6.8). The inventions claimed relate to the use of polyfructans sourced from blue agave to treat inflammatory diseases, the production of ethanol, and the creation of probiotic nutritional supplements, in addition to the distillation of alcoholic beverages. Interestingly, the greatest number of patent documents encountered through searches in Derwent Innovation®

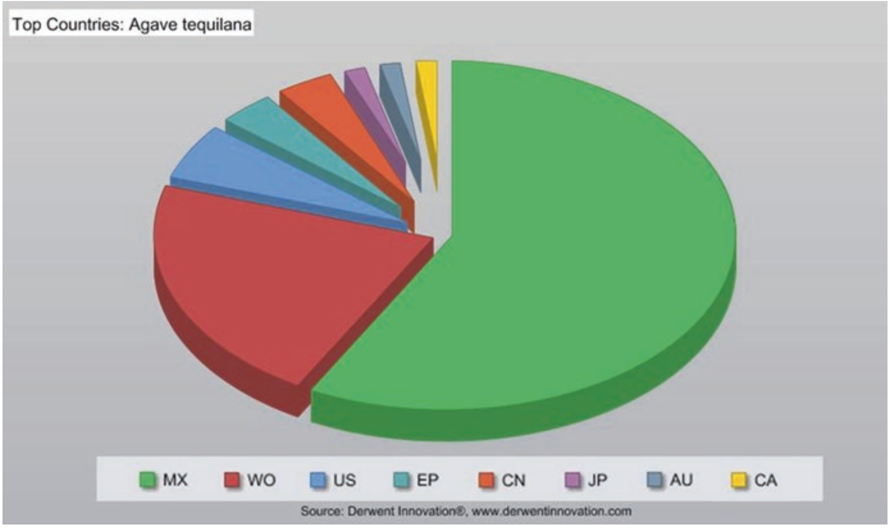


Fig. 6.8 *Agave tequilana* countries

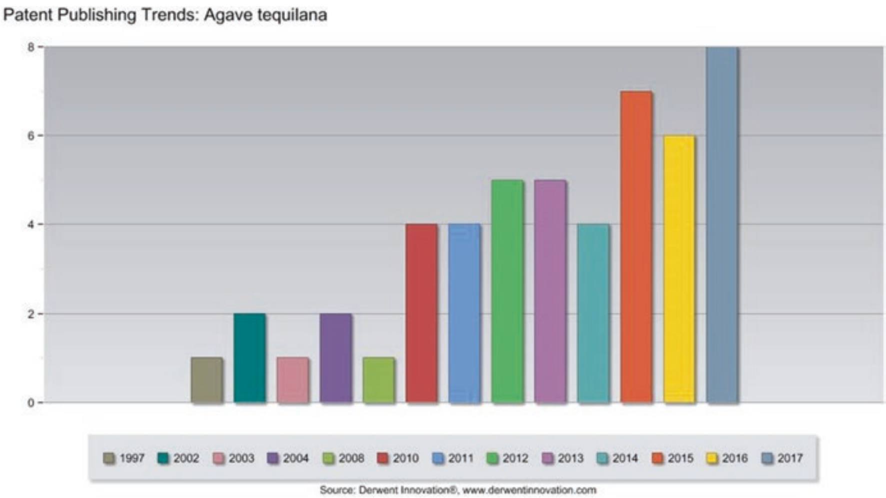


Fig. 6.9 *Agave tequilana* patenting trends

related to filings made in Mexico, with 26 total families in that territory (Fig. 6.9). This number was larger than the number of filings revealed through searches in the Mexican Intellectual Property Institute database. The discrepancy is likely due to the fact that many of the documents found through Derwent Innovation® were published in the past 3 years, and it is possible that these records have not yet appeared in the national database. The results demonstrated a clear increase in the number of filings over time in relation to *Agave tequilana*, suggesting that the entry

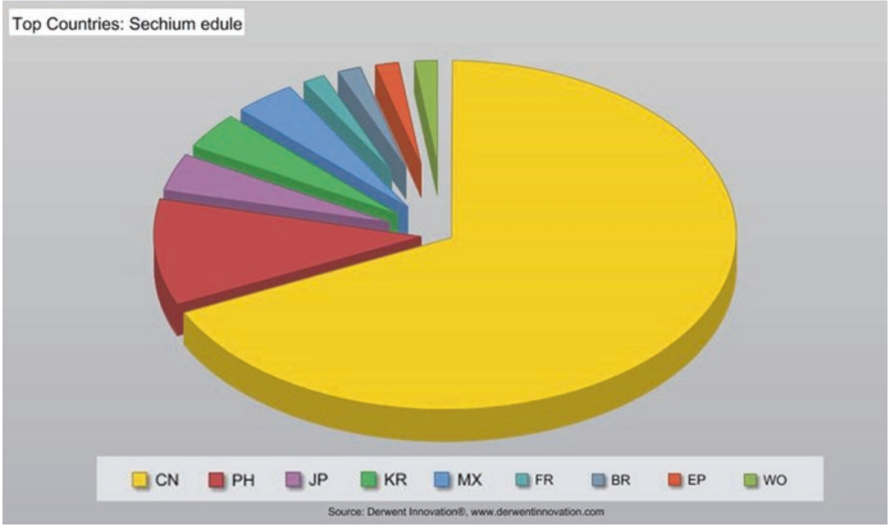


Fig. 6.10 Sechium edule countries

into force of the Nagoya Protocol – without the attendant national legislation to implement its provisions – has had little impact on intellectual property protection activity related to this plant species.

Finally, we examined international patenting trends related to *Sechium edule*, commonly known as chayote. This species is an edible plant belonging to the gourd family *Cucurbitaceae*, in which melons, cucumbers, and squash are also members. Chayote may be eaten cooked and served in a variety of dishes, and its fruit and seeds are rich in amino acids and vitamin C. The tuberous part of the chayote root is starchy, and it can be used as animal feed. Additionally, the leaves and fruit of *Sechium edule* have diuretic, cardiovascular, and anti-inflammatory properties, and tea made from its leaves has been used to treat arteriosclerosis and hypertension and to dissolve kidney stones (Aung et al. 1990).

Searches in Derwent Innovation® located 54 patent documents in 47 families with claims covering *Sechium edule* (Fig. 6.10). These documents related to the application of chayote for the treatment of a variety of ailments including diseases associated with endothelial dysfunction and hypertension, as well as constipation and acne, in addition to a variety of food-related uses. In contrast to the other two plant species that we examined, the majority of patent filings (32 families) related to chayote were made in China, while the second largest number of documents was found in the Philippines (5 families). Similar to the case of blue agave, the trends demonstrated a marked increase in the number of patent filings related to *Sechium edule* since 2013 (Fig. 6.11).

The results of the patent database searches that we conducted reveal that patenting activity in relation to the ten plant species of interest has tended to increase over time, both in Mexico and internationally. Assuming that the number of patent filings

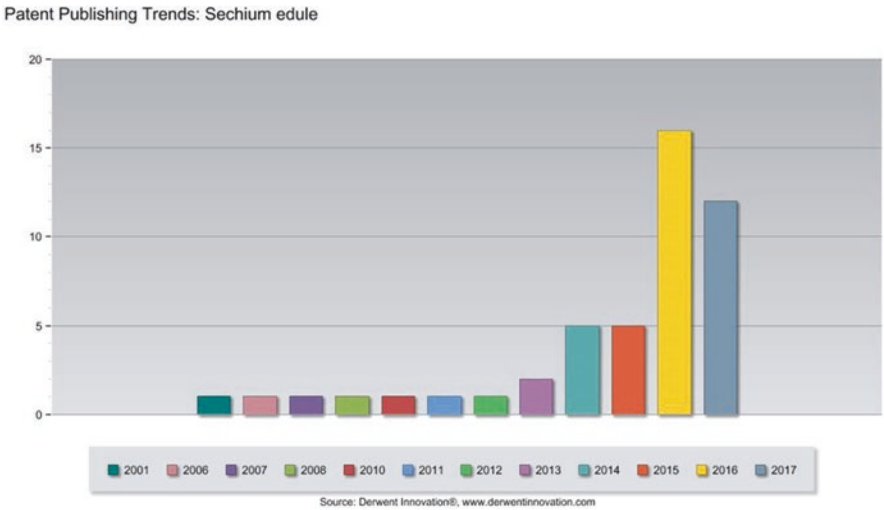


Fig. 6.11 Sechium edule patenting trends

related to such subject matter will continue to grow, inventors who utilize Mexican plant genetic resources as research inputs will need to remain vigilant about forthcoming changes to the legal framework for access and benefit sharing in Mexico. Additionally, while it is not the focus of this chapter, our findings indicate that patents may offer an effective means for the ex ante valuation of Mexican plant genetic resources, given the fact that multiple patent families exist across an array of technological sectors. Future research could develop valuation case studies based on the Mexican native plant species discussed in the present chapter, which in turn could inform prospective benefit-sharing agreements.

6.4 Conclusions

In this chapter, we have demonstrated that intellectual property rights in the form of plant breeders' rights and patents have been claimed in relation to a variety of Mexican plant genetic resources, both within the country and internationally. The data indicate that in general, applications for both plant breeders' rights and patents claiming subject matter derived from native Mexican plants have tended to increase over time. Yet it is still unknown whether increases in applications for intellectual property protection would actually correlate with a rise in the number of access permits applied for under national regimes based on the Nagoya Protocol or in the number of benefit-sharing agreements executed.

To date, only three permits granting access to genetic resources in Mexico have been made available to the Access and Benefit-Sharing Clearing-House administered by the CBD. This fact demonstrates that access and benefit sharing remains a nascent issue in Mexico but that the government is taking the implementation of the Nagoya Protocol seriously. The three permits were issued in July 2015, November 2016, and August 2017 to researchers located in the United States, Japan, and Spain, respectively. All were granted prior to the entry into force of the SAGARPA interim policy for the review of applications for access to plant genetic resources for food and agriculture. In the context of this new framework – and given the likelihood that Mexico will enact comprehensive and legally binding access and benefit-sharing legislation in the near future – researchers should take into account the need to comply with new, still-evolving regulatory procedures.

However, requirements to obtain an access permit or to negotiate prior informed consent or benefit-sharing agreements should not be considered impediments to the research process. As the data reported in the present chapter demonstrate, intellectual property activity related to plant genetic resources can intensify even as new frameworks for the governance of these resources are designed and popularized. Yet it remains to be seen whether the implementation of a national regime based on the Nagoya Protocol in Mexico might impact the activities of users and providers of genetic resources, including in relation to intellectual property protection. In the future, permit applications could serve as indicators of research trends, signalling areas of interest to potential collaborators or competitors. Meanwhile, intellectual property protections – in the form of plant breeders' rights or patents – could be used as proxies for the valuation of plant genetic resources. Then as now, Mexico will likely represent an important site in which the various dynamics related to the use of these resources may be unravelled.

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Chapter 7
Artisanal Fishers and Their Participation in Public Policies for Biodiversity Conservation in Their Communities

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Abstract Of the Mexican population, 46% live in coastal states, and most of them fish or are connected to economic activities around fisheries. In 2014, Mexico obtained revenues of US$387,574,351 from fisheries. Fishing drives development and strengthened in a sustainable form will support millions of families, but a correct instrumentation of public policies based on a real information exchange between government and social actors is needed. If a government is not capable of generating the abovementioned exchange of information, public policies cannot be instrumented correctly. Using a mixed methodology of surveys with fishermen and using the Likert scale, we were able to conclude that in the studied communities, it is not possible to speak about public policies, but we can figure out which government programs are lacking. The fishing sector has not been valued in its right dimension and has been displaced as a priority from the programs benefitting social and economic development within and outside protected natural areas.

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7.1 Introduction

Fishing is an activity that man has done since time immemorial. In the Stone Age, men were already catching fish, and with developing technology, fishing became more efficient and has generated a better quality of life in those places where fishing is practiced.

In Mexico, about 46% of the population lives in coastal states (OCDE 2007). In 2012, the domestic capture amounted to 1.66 million tons of fish. This is the reason why fishing is considered one of the elements that fosters the development of Mexico's coastal zones, and this economic activity must be vitalized by means of long-term sustainable instruments as a key challenge for the livelihoods of millions (Buhaya Lora and Ramírez Partida 2013). This implies the need to implement public policies that could solve the present social problems in fishing communities within and adjacent to protected natural areas (PNA). This is not only the responsibility of governments; the generation of solutions "is also a social responsibility that includes universities, research centers, organizations, social movements, and even citizens themselves" (Valencia Agudelo and Álvarez Yohan 2008).

The marginalization problems in the fishing communities cannot be solved only with the will of the government if there is no citizen participation. It is in these atmospheres where public policies are an option to modernize government actions. They are not only a useful and necessary alternative if they do not take into account the horizontal relations between government and citizens (Rodríguez-Manzanares and Gutierrez Linares 2010).

In this context two important aspects converge. The first one is that in our country, social policies to eliminate poverty and inequality have been inefficient to build and develop a model with social sensitivity looking forward to a collective well-being (Narro et al. 2013). The second one is that fishing policies implemented in our country do not permeate to attain a better quality of life in fishing communities; they do not show clear signs of being the result of a feedback process and commitment of all social and legal actors involved in this activity (Alcalá Moya 2003).

Public policies are understood as actions that face social needs, detonated from and by social participation, which makes them the interface through which government and society act to satisfy the requirements and priorities of the people. Not all governance is carried out through public policies (Rodríguez-Manzanares and Gutierrez Linares 2010), so it is pertinent to clarify that public policies should not be confused with government policies. The latter are actions directed at resolving public deficiencies and are designed and implemented with the intervention of any of the three government levels or all of them (Alfaro Jimenez 2016); so that the public administration will determine, according to the corresponding regulations, what challenges must be faced through the implementation of public policies and which through government policies (Montecinos 2007).

In Mexico, fishing is the primary source of protein for many low-income families and a potential developmental activity in Mexican coastal and rural localities; but this is not reflected in successful public policies or programs related to this activity, which has slowed down this sector with high potential development (Buhaya Lora and Ramírez Partida 2013).

In 1994, Mexico endorsed an environmental commitment and signed international agreements, such as the UN-led Code of Conduct for Responsible Fisheries (Alcalá Moya 2003), to consolidate this activity with sustainable practices. However, in Mexico, it is not possible to conceive a sustainable process by alienating economic activities from the quality of life of its actors; as explained by Ramírez et al. (2004) in *Sustainable Development: Interpretation and Analysis*, "sustainable development fundamentally aims to improve the quality of life of individuals in a society, guaranteeing the duration of natural resources and ecosystems ensuring the well-being of future generations; which must be achieved through policies aimed at ordering and limiting the pressure exerted by the different productive activities in their attempt to meet the needs of the population."

Therefore, sustainable development has to do with the formulation, coordination, and management of public policies that empower collective social actors, so that concerted and planned decisions, which should guide current and future public and private investments, take into account the criteria of balance and protection of the reproductive and regenerative capacity of the different types of capital: human, natural, physical, economic and financial infrastructure, and finally institutional.

Studies focusing on small-scale fisheries, public policies concerning fishing in natural protected areas (PNA), the attitude of fishermen to different aspects of fisheries regulation, as well as what fishermen suggest for their management assume that the effective management of this activity promotes not only the development of new rules that are appropriate for the biophysical and social characteristics of the fishery in item but also the internalization of those who take advantage of the resource in the premise that the rules must be understood and legitimized by all actors of this activity (Cinti et al. 2010).

In this area, successful practices have been found in the fisheries sector (see the Production Representation Units (URP) SOSD60000 and BCSSD12000 studied by Olmos-Martínez (2012)) – but despite these achievements, there are still weaknesses in the articulation of instruments designed by governments to strengthen fishing and, therefore, there are areas of opportunity in the construction of public policies (Alcalá Moya 2003).

It is clear that there are now a variety of opportunities in policies to strengthen fishing activity aimed at improving the quality of life of the fishing communities (Ardila 2003). So if a government is not able to generate the exchange of information and purposes between its entities and social actors, it will not be possible to establish public policies but only just government actions with a limited scope because the lack of social participation inhibits the access of the population to a better quality of life, since, in absolute terms, public policies have the prerequisite of the presence and participation of the actors (Valencia Agudelo and Álvarez Yohan 2008).

Therefore, the present study focused on determining successes and failures in the public policies implemented to improve the quality of life of two fishing communities in Sinaloa, Boca del Río and El Huitussi, in the municipality of Guasave, Sinaloa, through evaluating the opinion of the fishermen regarding the public policies implemented to improve the quality of life in their communities.

7.2 Fishermen Survey

Following the Rodwell et al. (2014) and Amigo-Dobaño et al. (2012) model, a survey was designed using Likert scales, with a series of items related to the subject that the researcher is interested in measuring, whose answers are requested from the surveyed subject in a degree of agreement or disagreement for each particular reagent (Padua 2000), as well as open answers to obtain informative data.

The survey consisted of two parts. The first part of the instrument was aimed at establishing the perception of the fishermen about the quality of life in their communities as a result of the different government programs applied in their communities, as well as the community participation in the design, instrumentation, and evaluation of these programs, with the following established items:

1. The quality of life in the fishing grounds of the municipality of Guasave is very good.
2. The government programs used to improve the quality of life in the fishing communities of the municipality of Guasave are appropriate.
3. Programs that are applied in the fishing communities of the municipality of Guasave solve the existing problems permanently.
4. The inhabitants of the fishing communities of the municipality of Guasave participate in the design of the programs directed to attend the social problems and urban infrastructure.
5. In the design of government programs aimed to improve the quality of life in fishing communities in the municipality of Guasave, do qualified specialists such as biologists, social workers, physicians, and engineers participate.
6. The relationship between fishermen and government agencies is excellent.
7. The inhabitants participate in the evaluation of the outcome programs that are implemented to improve the quality of life.

The second part of the instrument was informative, necessary to obtain data like age groups, levels of education, and some socioeconomic information, useful for designing contingency tables that allowed a deeper analysis of the information obtained.

Table 7.1 Surveys applied by landing site

Community	Fishermen	Surveys	%
Huitussi	792	258	32.57
Boca del Río	228	143	62.71
Total		401	100.00

7.3 Sample Determination

The sample was determined using the qualitative research formula designed by Sierra (1988):

$$n = \frac{Nz^2 pq}{(N-1)e^2 + z^2 pq}$$

where:

n: It is the number of the sample.
N: Size of the universe population.
z: Constant that depends on the level of trust assigned.
e: Error.
p: Probability of the event occurring.
q: Probability that the event does not occur.

The selected landing sites have distinctive characteristics. Huitussi, the largest community of both, depends basically on fishing, with very incipient activities that add value to their fisheries or diversify their economic activities. Boca del Rio, although it is basically a fishing community, has some parallel activities derived from its proximity to the beaches of Las Glorias and Buenavista, which allow the development of commercial and culinary activities. The formula was set at 5% error rate and was applied to the number of fishers registered by CONAPESCA for the selected landing sites. The survey was applied on the spot only by choosing fishers randomly, and the information obtained was systematized in the Statistical Package for the Social Sciences (SPSS), which obtained the frequency and percentage of the different responses obtained by each reagent.

7.4 Results

From the number of fishermen registered with CONAPESCA, a sample of 401 fishermen was obtained for the survey (Table 7.1).

7.5 Public Policies Perception of the Fishing Communities

The results showed that the largest age group of fishermen is between 51 and 60 years with 27.68% of the population, followed by groups of 31–40 and 41–50 years with 24.69% each. The data indicated that 41.15% of the fishermen only attended pre-school education, followed by 30.42% who had elementary education (Table 7.2).

It was observed that the actions that the fishermen consider to be of greatest importance for raising the quality of life are those related to economic development, 45% followed by welfare policies with 19.20% (Table 7.3). It was also determined that 75.81% of the fishermen had the perception that the retiring programs were of a charitable nature that improved the quality of life in the community (Table 7.4).

Item 1. The quality of life in the fishing communities of the municipality of Guasave is very good.

Table 7.2 Fishermen by age group and scholar level

Age group	Frequency	%
Less than 30 years (<30)	44	10.97
31 a 40 years	99	24.69
41 a 50 years	99	24.69
51 a 60 years	111	27.68
61 and more (>61)	38	9.48
Did not answer	10	2.49
Total	401	100
Schooling		
Preschool	165	41.15
Elementary	122	30.42
High school	61	15.21
Senior high school	15	3.74
Undergraduate school	22	5.49
Did not answer	16	3.99
Total	401	100

Table 7.3 Most important government actions to be implemented to improve the quality of life in the community

Variable	Frequency (%)		
	Huitussi	Boca del Río	Total
Public services	42	13	55
Economical support	123	60	183
Housing and urban infrastructure	38	15	53
Education and sports	1	3	4
Safety	5	3	8
Welfare	46	31	77
Others	3	18	21

Table 7.4 Government programs that improved the quality of life in the community and of those retired from operation

Variable	Frequency (%)		
	Huitussi	Boca del Río	Total
Public services	0	0	0
Economical support	38	16	54
Housing and urban infrastructure	0	3	3
Education and sports	4	0	4
Safety	213	91	304
None	0	33	33
Others	3	0	3

Table 7.5 The quality of life in the fishing communities of the municipality of Guasave is very good

	Frequency	%
Totally disagreed	109	27.18
Disagreed	230	57.36
Agreed	52	12.97
Totally agreed	1	0.25
Did not answer	9	2.24
Total	401	100

Table 7.6 Frequency of response by level of schooling and age

Schooling	Totally disagreed	Disagreed	Agreed	Totally agreed	No answer
Preschool	45	96	23	1	0
Elementary	30	74	18	0	0
High school	21	34	6	0	0
Senior high school	5	8	2	0	0
Undergraduate	6	14	2	0	0
Did not answer	2	4	1	0	9
Total	109	230	52	1	9
Age (years)					
<30	9	30	5	0	0
31 a 40	24	57	18	0	0
41 a 50	28	57	14	0	0
51 a 60	38	60	13	0	0
>61	10	25	2	1	0
Did not answer	0	1	0	0	9

In the evaluation of this item, 84.54% of the 401 fishermen stated that they disagreed with the quality of life in their community (Table 7.5). By the educational level of the fishermen, 90.9% of those who have a degree disagree with their quality of life (Table 7.6). By age groups, the group of 61 years or more responded disagree mostly with their quality of life in their community.

Item 2. The government programs used to improve the quality of life in the fishing communities of the municipality of Guasave are appropriate.

Table 7.7 The government programs used to improve the quality of life in fishing communities in the municipality of Guasave are appropriate

	Frequency	%
Totally disagreed	94	23.44
Disagreed	200	49.88
Agreed	87	21.70
Totally agreed	6	1.50
Did not answer	14	3.49
Total	401	100

Table 7.8 Response frequency per school and age levels

Schooling	Totally disagreed	Disagreed	Agreed	Totally agreed	No answer
Preschool	41	77	38	4	5
Elementary	25	61	36	0	0
High school	16	35	10	0	0
Senior high school	5	9	1	0	0
Undergraduate	2	17	2	1	0
Did not answer	5	1	0	1	9
Age (years)					
<30	10	29	5	0	0
31 a 40	15	57	21	1	5
41 a 50	20	50	28	1	0
51 a 60	38	43	30	0	0
>61	11	20	3	4	0
Did not answer	0	1	0	0	9

A total of 73.32% of fishermen disagreed that government programs used to improve the quality of life in communities are appropriate; 23.19% agreed with this statement (Table 7.7). Regarding the analysis of these data based on the level of schooling, the fishermen with higher schooling presented the highest percentage of disagreeing individuals, 93.33% (Table 7.8), whereas based on age groups, the group with the highest number of disagreeing individuals was the group of 30 years old or less, with 88.64%.

Item 3. The programs that are applied in the fishing communities of the municipality of Guasave solve the existing problems permanently.

A total of 84.29% of the fishermen disagreed with the fact that the programs applied in the fishing communities solved the problems permanently; only 13.47% of them agreed with item 3 (Table 7.9). According to the level of schooling, those interviewed with high and senior high school level presented the highest percentages of individuals in disagreement with the statement, with 93.44% and 93.33%, respectively (Table 7.10); in relation to the age groups, the groups between 41–50 years and 51–60 years presented the highest percentages with 88.89% and 88.29% disagreement, respectively.

Table 7.9 The programs that are applied in the fishing communities of the municipality of Guasave solve the existing problems permanently

	Frequency	%
Totally disagreed	104	25.94
Disagreed	234	58.35
Agreed	42	10.47
Totally agreed	12	2.99
Did not answer	9	2.24
Total	401	100.00

Table 7.10 Response frequency per school level and age

Schooling	Totally disagreed	Disagreed	Agreed	Totally agreed	No answer
Preschool	46	89	24	6	0
Elementary	27	81	10	4	0
High school	20	37	4	0	0
Senior high school	7	7	0	1	0
Undergraduate	4	14	3	1	0
Did not answer	0	6	1	0	9
Age (years)					
<30	13	28	2	1	0
31 a 40	17	61	18	3	0
41 a 50	25	63	8	3	0
51 a 60	33	65	10	3	0
>61	16	16	4	2	0
Did not answer	0	1	0	0	9

Table 7.11 The inhabitants of the fishing communities of the municipality of Guasave participate in the design of programs aimed at addressing social and urban infrastructure problems in their localities

	Frequency	%
Totally disagreed	115	28.68
Disagreed	179	44.64
Agreed	89	22.19
Totally agreed	7	1.75
Did not answer	11	2.74
Total	401	100

Item 4. The inhabitants of the fishing communities of the municipality of Guasave participate in the design of programs aimed at addressing social and urban infrastructure problems in their localities.

The data collected allow us to establish that 73.32% of the fishermen disagreed that the inhabitants of the fishing communities participate in the design of the programs aimed at meeting their requirements (Table 7.11). Regarding the academic level, the highest percentage of fishermen in disagreement was the high school group with 93.33% (Table 7.12). The results by age groups established that the group of 41–50 years, with 78.79% of fishermen, disagreed.

Table 7.12 Response frequency per school level and age

Schooling	Totally disagreed	Disagreed	Agreed	Totally agreed	No answer
Preschool	43	75	41	6	0
Elementary	35	55	29	1	2
High school	19	33	9	0	0
Senior high school	11	3	1	0	0
Undergraduate	6	11	5	0	0
Did not answer	1	2	4	0	9
Age (years)					
<30	12	20	9	1	2
31 a 40	36	37	26	0	0
41 a 50	36	42	21	0	0
51 a 60	20	61	27	3	0
>61	11	18	6	3	0
Did not answer	0	1	0	0	9

Table 7.13 In the design of government programs aimed at improving the quality of life in the fishing communities of the municipality of Guasave, qualified specialties, such as biologists, social workers, doctors, and engineers, participate

	Frequency	%
Totally disagreed	71	17.71
Disagreed	176	43.89
Agreed	137	34.16
Totally agreed	6	1.50
Did not answer	11	2.74
Total	401	100

Item 5. In the design of government programs aimed at improving the quality of life in fishing communities in the municipality of Guasave, qualified specialists, such as biologists, social workers, doctors, and engineers, participate.

A total of 61.60% of the fishermen disagreed with this item (Table 7.13). Of those surveyed with high school studies, 80% disagreed with this assertion (Table 7.14), whereas in the age group of 61 years and older, the highest percentage (86.84%) disagreed with this item.

Item 6. The relationship between fishermen and government agencies is excellent.

Table 7.15 shows that 79.55% of the fishermen disagreed with "the relationship between fishermen and government agencies is excellent." Likewise, 100% of the fishermen with high school studies disagreed with this assertion (Table 7.16). The result generated from the age groups who disagreed with the relationship between fishermen and government agencies is excellent and is for the 30 years or less group with 86.36%.

Item 7. Inhabitants participate in the evaluation of the result of the government programs that are implemented to improve the quality of life.

Table 7.14 Response frequency per school level and age

Schooling	Totally disagreed	Disagreed	Agreed	Totally agreed	No answer
Preschool	28	76	56	5	0
Elementary	19	58	43	0	2
High school	11	27	23	0	0
Senior high school	8	4	3	0	0
Undergraduate	3	10	8	1	0
Did not answer	2	1	4	0	9
Total	71	176	137	6	11
Age (years)					
<30	10	15	17	0	2
31 a 40	21	36	41	1	0
41 a 50	20	49	30	0	0
51 a 60	12	50	48	1	0
>61	8	25	1	4	0
Did not answer	0	1	0	0	9

Table 7.15 Is the relationship between fishermen and government agencies excellent?

	Frequency	%
Totally disagreed	74	18.36
Disagreed	246	61.04
Agreed	65	16.13
Totally agreed	4	0.99
Did not answer	14	3.47
Total	401	100

A total of 78.30% of the fishermen disagreed with the fact that the inhabitants participate in evaluating the results of government programs implemented to improve the quality of life (Table 7.17). In Table 7.18, fishermen with high school level have the highest percentage of individuals disagreeing, with 93.33%, and 86.87% of the group of 41–50 years disagreed with the assertion.

7.6 Discussion

The "Social study of fisheries in Mexico: a diagnosis of the social problems of fishermen, their environment and their vision on possible solutions to problems affecting fishing" by CONEVAL establishes that the quality of life in fishing communities of Mexico is well below the levels of well-being (FAO 2010). In Huitussi and Boca del Rio communities, the quality of life has gradually declined, due to the continuous depletion of fishing. The public and government policies that have been implemented to strengthen the fishermen's way of life face a difficult challenge in the absence of systematized and reliable information of statistics, because monitoring or

Table 7.16 Response frequency per school level and age

Schooling	Totally disagreed	Disagreed	Agreed	Totally agreed	No answer
Preschool	31	98	29	2	5
Elementary	19	85	17	1	0
High school	12	42	6	1	0
Senior high school	6	9	0	0	0
Undergraduate	4	9	9	0	0
Did not answer	1	3	3	0	9
			Age (years)		
<30	10	28	4	2	0
31 a 40	24	61	14	0	0
41 a 50	14	69	16	0	0
51 a 60	18	65	23	2	3
>61	6	23	7	0	2
Did not answer	1	0	0	0	9

Table 7.17 Inhabitants participate in the evaluation of the results of the government programs that are implemented to improve the quality of life

	Frequency	%
Totally disagreed	143	35.66
Disagreed	171	42.64
Agreed	72	17.96
Totally agreed	2	0.50
Did not answer	13	3.24
Total	401	100

evaluation of policies already implemented considering social, economic, and environmental aspects is scarce (CEDRSSA 2006).

In addition, poor education is an important factor that accompanies poverty, whereas, according to the OECD, good education strengthens the fisheries sector, because education has a high potential for change (OCDE 2007). A low level of education is not only a limitation for fishermen to carry out economic activities that are different or different from fishing, which can best meet their needs and those of their families, and are determinant for the parameters to define quality of life.

In this sense, most of the fishermen have the perception that the promotion of the economy has to be done through assistance programs. These perceptions are a reflection of the classic treatment of community problems, in keeping with the traditional idea that the public administration should promote the rational use of resources by increasing the generation of goods and services, as well as filling the gap of minimum satisfactions that a community should enjoy (Méndez 2000). However, this is also an approach that excludes other factors intimately linked to human development and well-being, which can only be achieved with the proper training of individuals through education (OCDE 2007).

The well-being and quality of life of the fishing communities depend on the satisfaction of their basic human needs, which can no longer be measured by income indicators alone but by meeting other needs such as correct food, access to health

Table 7.18 Response frequency per school level and age

Schooling	Totally disagreed	Disagreed	Agreed	Totally agreed	No answer
Preschool	63	68	32	0	2
Elementary	39	59	23	1	0
High school	22	31	8	0	0
Senior high school	11	3	1	0	0
Undergraduate	8	7	6	1	0
Did not answer	0	3	2	0	11
Age (years)					
<30	10	23	9	0	2
31 a 40	36	42	21	0	0
41 a 50	49	37	13	0	0
51 a 60	35	50	25	1	0
>61	13	18	4	1	2
Did not answer	0	1	0	0	9

systems, public safety, and access to quality education. Like other fishing communities where the level of well-being is well below the national average indicators (FAO 2010), in the communities that are the subject of this study, the quality of life presents great areas of opportunity, as indicated by 84.37% of the fishermen, who answered that the quality of life in their communities is very good.

Public policies are to be implemented to solve or mitigate a problem, which necessarily implies establishing an objective, generated from a correct diagnosis and with a clear design of the corresponding strategies. However, it is not surprising that although a public policies endeavor starts with the correct definition of the problem, a general objective, and strategies to implement clear and concerted actions, sometimes the defined actions are not executed according to the projection, and although it is true that the administrative principle of flexibility needs to be addressed in planning processes, actions are not well executed due to the lack of resources – financial, technological, and personal – or legitimacy (Méndez 2000).

When a government program does not count upon the confidence of the population, it not only fails to achieve the objectives for which it was raised and implemented but can neither be a public policy. In the communities that are the subject of this analysis, the general perception of the fishermen surveyed is that different levels of government have not been able to harmonize the human needs of their inhabitants, which is a prerequisite for reconciling economic growth, social solidarity, and the growth of people in those communities (FAO 2010).

On the other hand, the fishing communities *do not* participate in the design of programs aimed at addressing the problems that these communities suffer, and, according to the analyses, this perception is independent of age or academic level. In this context, these results are highly relevant because several recommendations have been made to the entities responsible for the social aspects; fisheries and environmental policies establish the need for the participation of fishing communities in the design of strategies, such as participatory management (CEDRSSA 2006). In addition, Mexico has a large number of cases of failures in the articulation of public policies and programs – in many cases because the origin of their design has a theoretical and centralist approach incapable of responding to the real needs of a community – and the perennial risk of public policies of being government programs disguised as public policies, by including in some part of the process of their design or implementation the participation of some social group, which, in addition to not turning them into public policies, unfortunately, is a constant practice at the different levels of government. According to Mauricio Merino, "... public policy must be genuinely public from the outset: designed by those who have to participate in its execution, transparent at the time of implementation, and clearly responsible for the resources employed by the government, but also by society ..."(Méndez 2000).

However, development planning must combine government policies with public policies, and both require the inclusion of experts, especially for communities with such large levels of marginalization, which also face the challenges of avoiding the complete exhaustion of the natural resource they exploit to survive, the inadequate management, and pollution generated in a context that goes from local to global: "The process of eliminating poverty in a country and, therefore, in fishing communities is not only a matter of regulating efforts and catching patterns, but also the need to institutionalize programs for fishing, aquaculture, and research to mitigate poverty, but they must be multidisciplinary and effective for the whole country that suffers poverty ..."(CEDRSSA 2006).

The human environment of the fishing communities of Mexico is described as respectful and friendly, which creates an atmosphere conducive to unify the efforts of the community toward the solution of the problems that afflict them (FAO 2010), but the relationship between fishermen and government agencies lacks excellence. The result of the analysis of the data generated during the survey is in accordance with the information and field notes generated during the survey process used in this research and suggests that the relationship with the authorities is governed by the degree of convenience because of the fishermen's position relative to only meeting satisfactorily their needs and of their families.

Evaluation is a very important part of the cycle of all public policies, because this part of the process allows establishing the results generated by their implementation, establishing a balance between the objectives defined, and the effect they are actually generating. This is why evaluation is of crucial importance in the formulation and implementation of public policies. However, in practice, this process cannot be implemented with the clarity and precision that administrative theory demands (Pardo 1990). This situation is not present in these communities because fishermen *do not participate in the evaluation of the results of government programs*, and sometimes the evaluation that is done is a mere protocol. In such a context, inadequate evaluation does not allow the generation of important information for the management of public policies, such as the knowledge – in time and form – their development, the investment made, fulfillment of the objectives, and the established times to take advantage of the opportunity areas presented, which will provide knowledge for their successive improvement (Quiñones 2008).

7.7 Conclusions

There is great discomfort among fishermen regarding the programs and public policies implemented in their communities. They consider that programs are not appropriate for their communities and are used discretionally to pay political favors. In addition, they do not trust their leaders, who concentrate the power of management in the face of governmental entities and use it as a usufruct. Since there are no programs aimed at strengthening the social sense of belonging, it is necessary to unify efforts around common goals. The general perception is that governments have been unable to implement actions that satisfy the human development needs of fishing communities and that the programs that the public sector brings to their communities are palliatives that try to remedy the problems, but not their cause. The quality of life in fishing communities is poor, and they suffer from a low standard of living despite being immersed in areas where it is stipulated that there must be a social benefit to foster social development and promote the conservation of human resources.

It has not been possible to identify any governmental strategy that, in itself, or in an articulated way, has constituted or constitutes a basic element to improve the quality of life in fishing communities, but without the actual participation of the community to which they are directed. In addition, they lack vertical and horizontal alignment among the different programs and public policies that affect the quality of life of fishing communities. The intervention of the communities in the processes of planning, instrumentation, and evaluation of social programs is none, contrary to the framing of a public policy. The fishing sector has not been valued in its right dimension and has been displaced as a priority from the programs benefitting social and economic development within and outside protected natural areas.

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Part II
Theoretical Aspects

Chapter 8
Socio-environmental Aspects of Conservation in Rural Communities

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Abstract Rural communities immersed in protected natural areas have local ecological knowledge of the species that exist in their environment, which could be closely related to the management that can be provided to the area. In this sense, the involvement of communities is extremely important in conservation, since they are the ones that make use of the natural resources that surround them.

Keywords Multicultural · Biodiversity · Socio-environment · Culture · Local management

8.1 Introduction

As is well known, Mexico has a biocultural heritage of vast proportions, this being understood to be the conjunction of high biological diversity (fifth country in terms of number of species) with cultural variety, comprising a little more than 68 different linguistic groups (INALI 2008), which are combined in a complex biological-cultural perception and appropriation of the environment, leading to a landscape that has been maintained from generation to generation, basically by oral tradition. That is to say, the inhabitants of a place (whether indigenous or nonindigenous) have empirical knowledge of the nature that surrounds them; they know about the life cycles of organisms, intraspecific and interspecific interactions, as well as the physical environment. Further, this knowledge transmitted by oral tradition is usually implemented through management of the species, either through their

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domestication, e.g. apiculture, or for the utility they provide, such as for food, including up to the present-day administration of species for subsistence hunting, therapeutic use, or as material for the building industry (mainly plants). As Toledo and Barrera-Bassols (2008) pointed out, "each local culture interacts with its own local ecosystem, and with the combination of landscapes and their biodiversity contained within them, so that the result is a complex and wide range of fine and specific interactions".

For this reason, the rural environment is an experimental field of perceptions, appropriations, uses, and worldviews on the part of the people that interact with their environment. In this respect, the Instituto Nacional de Estadística y Geografía (2009) at its last ejido census recorded that in the country, there were 31,514 (ejidos and agrarian communities), which possessed 105,948,306.16 ha, representing 53% of the national territory. This indicates that a large part of the surface of Mexico is located in a rural environment mainly managed by farmers, ranchers, and/or indigenous peoples.

In this sense, the peasants, with Mesoamerican "tradition", and indigenous peoples are involved in both the natural protected areas and outside them. Experience shows that given appropriate political and social conditions, the protection of indigenous and peasant natural resources by means of managed landscapes is relatively efficient in some areas of the country. This was how community forest management entered the Sierra de Juárez, Oaxaca, Quintana Roo, Durango, and Michoacan areas, among others. Several regions considered pristine from the biological point of view are landscapes directly or indirectly under the influence of human culture, changing the relations between species, plant and animal communities, ecosystems, and the environmental services as a whole (Boege 2008).

It has been seen that managed ecosystems are a constant in the Mexican landscape, and protected natural areas are not the exception, since for the most part they are villages included in the polygons or have an influence on them. If there is a recapitulation of the PNA in Mexico and its relationship with the communities immersed in them, one can observe a transformation in the way that the inhabitants of rural communities have been included: either with their presence alone – it should be recalled that in the beginning, the decrees of the reserves excluded the rights and conservation were carried to an extreme, the establishment of population centres within the polygons although with innumerable constraints – until facts of governance and management on the part of communities within the PNA were considered.

In accordance with the analysis of the census information on the national territory carried out by Bezaury-Creel et al. (2009), close to 900 PNA have some federal, state, or municipal district, and moreover in the areas intended voluntarily for conservation as certified by the Federation and the private PNA and communities, 279 of them had the presence of human settlements. The registered population in the PNA in the year 2005 (approximately 3,470,448 inhabitants) represented 3.34% of the total national population. The inhabitants registered in PNA (2,591,147) in the year 2005 accounted for 2.5% of the total population of the country and 5.7% of the rural population (1,378,376 inhabitants) (Fig. 8.1).

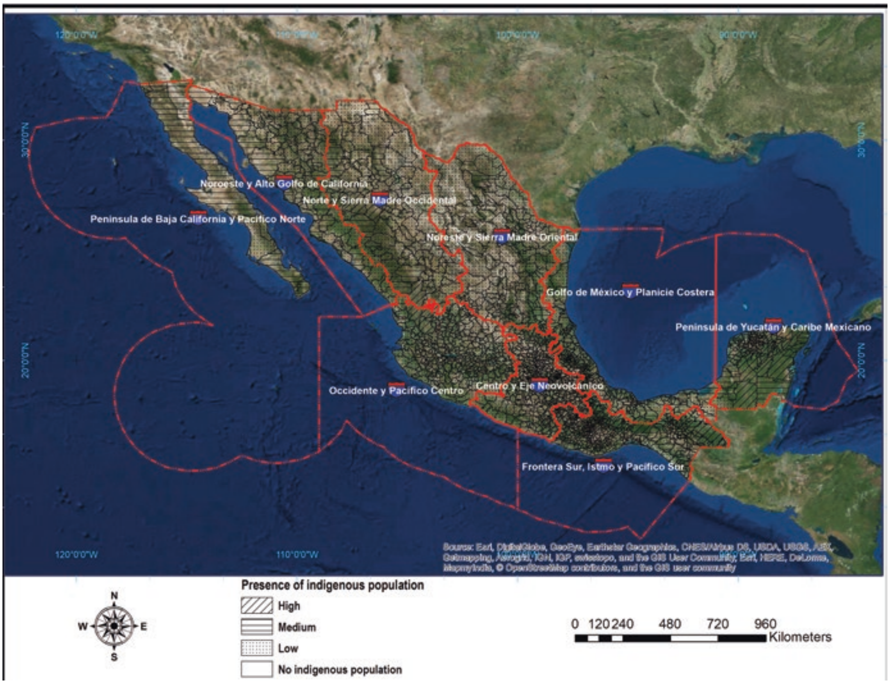

Fig. 8.1 The presence of indigenous populations by region of the National Commission of Protected Natural Areas

8.2 Use of Natural Resources

The settlements within or adjacent to protected natural areas possess a wide range of possibilities to make use of the environment, due to the high biodiversity that can be found in these places.

In this regard, Moreno and colleagues (2014) reported that the relationship between the diversity of peoples – whose occupations include farmers, ranchers, fishermen, and traders among others – and the rich biological diversity that characterises the territory has led to a high biocultural variety that is represented through:

A. The domestication of about 200 species of plants which are very important at the global level, such as maize, several species of beans, chilli, squash, and amaranth, cotton, and cocoa, to name a few; an example of this is the system of milpa maya that included several of the species referred to that were enriched with tubers and vegetables (Terán and Rassmusen 1994).
B. The incipient domestication of several hundreds of species of local or regional importance, among them a great biodiversity of cacti, legumes, cucurbits, quelites, fruit trees, and shrubs.

C. The ethnobotanical knowledge of close to 7000 of the 24,000 plant species registered in the country. Among the works which can be reviewed are authors such as Faustino Miranda (1946, 1963), Alfredo Barrera Marin (1976), Barrera Marin (1994), and Aguilar and Zolla (1982). In regard to ethnozoology, it has worked with hundreds of species of insects, mainly from the nutritional point of view; to elaborate on this group, the work of Ramos-Elorduy (1997, 2001, 2002, 2005) can be viewed. With regard to the birds, mammals, amphibians, and reptiles, these are used as resources and are part of the worldview of the Mexican towns; there are many works about the forms of hunting (Naranjo and Bodmer 2007), animal healing (Enriquez et al. 2006), and the uses made of the remains, such as bones and skin (Morales and Villa 1998; Enriquez et al. 2006), and even where they have been used as symbols, (see the work of Marco Vázquez-Dávila 2014; Lourdes Navarijo 2000, 2008).
D. In the development of important traditional systems of forest management, agroforestry, and agriculture, most of which are of Hispanic origin and the presence of which can be verified in the present, as well as others that were developed with the addition of species and techniques of ecosystem management postconquest and during the European colonisation (Barrera-Bassols and Toledo 2005; Moreno et al. 2014).

According to research by Boege (2008), Oaxaca, Chiapas, Veracruz, Guerrero, and Michoacán have the greatest concentrations of diversity at the national level and also have the largest presence of indigenous peoples. Therefore, one of the strategic lines for the sustainable management of natural resources (biodiversity, soils, water resources, environmental services) is the recognition of indigenous peoples as social subjects central to conservation and development at the national level. This is based on the understanding that indigenous peoples are social subjects in both their cultural construction and the precise ways in which they are linked and interact with their natural resources and their environment. For this reason, we consider it appropriate to understand the concept behind the already ancient vision of man-nature, providing concrete examples on how to assume ownership of the environment and to generate knowledge that is manifest from the culture itself, for its implementation in daily practice.

With regard to the knowledge and management of the environment that can be done by indigenous communities, it can be shaped by the Mayan culture in the Yucatan peninsula, as pointed out by Toledo et al. (2008). The collected studies deal with the use of a diversity of plants – as mentioned above – in the milpa (***kool*** in Mayan language) and that it is not only specific to the productive period of maize but is also linked to the forestry management of the succession of different stages of rest we give to the habitat to recover. They also deal with other productive activities that are not exclusive to the area but that are adopted by the inhabitants of the different localities studied, such as the use of family gardens, the meliponiculture and/or beekeeping, hunting, gathering, and extraction of different species of plants of the *monte*.[1]

[1] Monte is an uninhabited area with vegetation in recovery

An example of the conjunction between conservation and the use of resources by the residents of a Maya community is the one that is located in the village of Punta Laguna, located in the municipality of Valladolid, Yucatan. This site has a medium jungle vegetation and wetlands, the refuge of various animals, among them the spider and saraguato monkeys, and is also the habitat of the puma and jaguar. The inhabitants of the place realised this great biodiversity from the 1970s and led by the family Canul managed to persuade the authorities to declare the site as a protected natural area. Finally, in March of 2000, a baseline survey was conducted of the new Area of Protection of Flora and Fauna (APFF) of name Otoch Ma'ax Yetel Kooh (the house of the monkey and the puma). Subsequently, on 5 June 2002, the decree of creation as PNA with the category of APFF with a surface area of 5,367-42-35 ha was published in the Official Journal of the Federation (DOF). With this, a cooperative of the inhabitants of the locality (***Nahil tucha***) was formed, to ensure the protection of the environment and the effective use of resources through ecotourism.

8.3 Ruralidades, Environment, and Everyday Life in Locations in the South of Yucatan

Based on what has been stated up to now, the information and ideas provided in the previous pages, it is natural to assume that the so-called Mayan communities, or people in general, maintain a relationship based solely on pre-Hispanic beliefs through which it is interpreted that the villagers sought to maintain the "cosmic balance" through grants, permits, and reciprocity. While some ethnographies and ethnobiological reports have detailed the prevailing meanings, symbols, and rituals associated with the work in the field, the reality of today shows us cultural transformations in a different sense. On the one hand, the constant abuse of corn fields through cultivation based on the techniques of tomb and slash-and-burn has damaged soils, rendering them unusable for decades. On the other hand, the cultural changes referred to above not only imply the transformation of agricultural rituals and symbols but also the diversification of the areas of cultivation, as well as the products which are sown.

In a state where the henequen served as a historical product – today endangered/under threat of disappearance – and the fields are the most associated with the regional culture, the entry of products derived from vegetables together with "nonlocal" fruits such as lychees and passion fruit, as well as those derived from honey and coconut, leaves in doubt the survival of crops taken through "traditional" processes. In this sense, elements such as international migration and interstate migration mainly towards the Riviera Maya have had an impact on the sociocultural transformation already mentioned, as well as the diversity of productive activities. In virtually all localities qualifying to be called "cities" by virtue of their demographics, people now focus on trade, leaving aside agricultural activities or the hunting of species such as the raccoon or deer *Odocoileus virginianus*, to mention a few, although the practice persists.

In municipalities in the south of the state, particularly Tekax, Oxkutzcab, and the villages of cooperatives where more migration to the USA is perceived, temporary grounds have gradually given way to more sophisticated irrigation systems. However, considering that people are still linked with the natural environment, although the traditional crops have ceased to be the most income generating, people still maintain the milpa, horticulture, hunting, and activities on the monte. Many of them argue that maintaining their "farms" is a custom or because these were inherited from their parents and this is a way to remember them. Even some groups of people returning from the USA take the opportunity to "go to see their crops". Hence, some customs still remain – although far from retaining their traditional meanings – and the relationship with the monte and natural environment always prevails, from which they learn how to socialise, how to work, and how to gain knowledge about reading the landscape and the symbols. Therefore, the people of the fields know at what time and hours of the day trees are cut. They know not to take advantage of the resources without asking permission from the owners of the monte, without raising a prayer, or without even naming your loved ones Rodriguez Balam (2010).[2]

It is also a fact that whoever does milpa and does not express gratitude to the owners of the monte will lose their land, and it will become sterile. In the same vein, after each harvest there should be an agricultural ritual of thanks for the food collected. It is an offering to the deities, the "chaques" and lights that take care of the monte.

If the corn and the work in the field are important, it is also vital to recognise that the monte is fundamental, to the extent that ignoring their ways, roads, and designs could lead to tragic consequences. So the villagers of Huntochac and Oxkutzcab explain, "getting in the monte is dangerous, even more than the sea. If you don't know what trees there are and how to walk in the monte you can lose and never leave".

And it is apparent that this space has dangers, whether you go to planting, clean a field, or go hunting; various animals can attack, and the guardians of the monte or bad spirits can lead a person to spaces and times other than those of the earthly life. The monte "you lost". Some of the inhabitants of localities in the southern part of the state recount that people getting lost on the monte is a common occurrence.

On one occasion, a person lost in the monte was sought for days. It was a hunter who went in search of a deer he had shot. He followed the deer into a cave and found himself in another space, another time. The fields were large, with green pastures full of pens with cows and horses. Suddenly, the master of the ranch called him and asked him what he was doing there. To know him, it was commanded to lock him up in a jail for all to see. In the evening, a turtle approached him and told him that he would help him to get out of jail.

So the turtle was able to secretly take the keys, and the hunter was able to open the door of the prison. He left the place and escaped in a hurry. Returning by the same path and out again through the cave, he went to his house. His family were astonished to see him, as he had aged considerably, and his face was that of an old man. He was

[2]A version of the text referring to the beliefs on the monte and the story of hunting were published in my text called: "The monte and hunting: Building Spaces, transforming practices" PP. 101–119, Peninsula, Vol. 5, number 2. CEPHCIS-UNAM, Mérida, Yucatán, 2010. ISSN 1870–5766.

counselled by the elders not to reveal what had happened to him. But he did not heed their advice and told everyone about it, and so he fell seriously ill and died.

In this story we can see not only the idea of reciprocity with the natural environment, even in areas adjacent to the urban limits, but also the aspirational wishes within productive activities. The passage of the agriculture and livestock breeding laws in municipalities of the state seems to have opened the door to different vocations within the productive activities. This is also reflected in the way the communities use the resources at their disposal, either the milpa or agriculture in general, beekeeping, livestock, or trade.

Despite the fact that, as we have seen, the activities related to the monte involve symbolic elements and rituals, this does not imply a change in beliefs, practices, and production. In fact, there are certain locations in the south and east of the state where they carry out more than three types of activities related to the field as well as with trade and migration.

In the case that concerns us, we can say that the southern part of the state of Yucatan is a region that confronts us with a reality that is diverse not only in terms of the special geographical features, flora and fauna, but also with regard to the continuing social transformations (social, political, and religious), a situation that makes it appear as a complex area. Without a doubt, the attention to the manner in which its people have understood the need to share and negotiate spaces (of power) is characterised, among other things and in contravention of the homogeneity of the Yucatec Maya, by its being a territory in open inter-ethnic coexistence among Yucatec Maya, Mestizos and, at least in the last decade, with Chol. In such contexts, maintaining elements and diagrams attached to the "tradition" or taken by the Maya in an area where the natural environment, the phenomenon of migration and its consequent impact on the economy are very persistent and require much more than just protest and commitment on the part of a few.

As has been said before, the economic vocation in the southern part of the state has overturned, at least since about three decades ago, the practice of horticulture (particularly in the municipalities of Oxkutzcab and Tekax). Today, the market and trade in the area depend to a large extent on the sale and movement of products such as sweet-and-sour oranges, lemon, and the habanero chilli, among others. Economic activities, however, have not been limited to work in the field; precisely because of its geographical environment, livestock breeding and trade have been shaping an increasingly complex schema within the economy of the region. There is also a strong emigration, which is not limited to the USA, because people were also aware of the possibilities that the capital cities or resorts offer in terms of better-paying jobs (the cities of Merida and Cancun, primarily, but also the Riviera Maya).

However, neither the emigration nor the changes in the household economy have prevented some people from continuing to be linked with practices held as "traditional"; activities such as hunting have also been related to beliefs within practical and symbolic visions of a space (beyond the borders of the milpa), essential to understanding the Maya of today: the monte. This is a space where some stories have retrieved their narrative, not only in a series of activities linked to practices and rituals but also in a variety of spaces of fuzzy and blurred contours that have been reproduced and express the culture.

From our perspective, the relationship of the peasants and horticulturists with the monte is a relationship mediated by power and control. The idea of control, possession, and ownership of a territory with its consequent "domestication" is always fundamental to understanding this interaction. An ethic of respect, values, and norms involves understanding the struggle to dominate a territory in relation to another (both actively and dynamically) through complex negotiation mechanisms, ownership, and securing a space that in principle, it should be understood, must be seen from the nonmembership perspective. We refer here to the political idea in its most direct sense; the ability to govern is both the ability to sort spaces and to direct the actions of the subject. From the human perspective, it is to glimpse the gestation of forms of organisation that operate from a speech created in a space that it is necessary to appropriate. It is a socially constructed space, which at the same time is presented as a place of social interactions and of symbolic order.

A "new knowledge" that is transmitted orally and that requires traditional knowledge as well as those acquired over time implies knowing the names of chemicals used as compost, fertiliser, new cultivation techniques, as well as quantities and measures, among other things. If in addition to the above we take into account the fact that the economy of a good part of the population rests in the fruits that can be grown (which makes it necessary to know prices, costs, and market networks), we can realise that the irrigation system is vital for the daily life.

Although the importance of irrigation systems carries relevance even within religious and symbolic frameworks of worship, in what has been agreed to give Catholic masses and prayers of pastors, we do not intend to say that the water pumps are element generators of cults or that they have become sacred objects and therefore symbolic environments conducive to interpretation. Without doubt it is a fact that if it comes to a point where Protestant and Catholic are a common reference and even, from our perspective, only at times becomes a space that fosters religious expressions and ecumenical gatherings.

Taking into account the complexity of the sociocultural environment of the Maya of the southern part of the state, we can observe a little more closely the way in which they have been related with nature. We cannot overlook the fact that beliefs, religious practices, rituals, and cosmovision (worldviews) require going beyond the symbolic multiple readings that lead almost by default, to look at the social construction of reality framed in the dynamics of change and permanent adaptation from the social sphere.

Thus, the religions, for example, must be seen as relating to different and more complex aspects than the mere denominational affiliation. These beliefs and practices within a given context will always have the support of the durability of the sociocultural processes and practices that they contain. In this sense, the transmission of knowledge does not remain anchored in the axes that we have built and established as "traditional" from anthropology and history, but has to adopt and adapt new ways of knowing the social world and the natural environment in which it develops.

In communities where the irrigation systems and the processing work are of vital importance for the economy of the families, knowing what lands are good to work, how deep it is required to drill for a well, where are the veins of water to go around with a tube and bring the liquid to the land, as well as being clear about what type of fertiliser or herbicide to use are today part of a knowledge which is appropriate and has been transmitted to enable living together within reconfigured new patterns of life, consumption, and cultural practices.

In the monte as a generator of social interaction, the hunting of deer with the beliefs that accompany this activity, as well as the migratory phenomena, economics, and religion, we speak of a diversity of regions within the national territory that not only are permanent, and also the dynamics of a complexity that should lead us to rethink old categories of the "indigenous", the "traditional", the "permanence", the "cultural change", as well as old dichotomies such as "rural vs urban" that today do not work as they did decades ago, in the ethnobiological analysis of social or geographical boundaries. In that sense it may be more appropriate to focus on concepts and research the most appropriate methodologies with regard to the way people constantly insert amendments to the interaction and interpretation of the environment.

It is precisely cultural practices informed with knowledge and appropriation of the means that surround them, which show us the assimilation of contexts designated as "rural" or "urban". If the ethnic groups have been able to transform their knowledge and adapt, and adopt other mores without abandoning their beliefs, we believe then that his study also requires new approaches and analytical categories.

In such a scenario, it is difficult not to suppose that, notwithstanding ineffective idealizations, the use and abuse of resources is not always caused by the companies and transnational corporations but also by the villagers themselves. In that sense, programmes of support to both the field and the companies will have to take into account not only forms of true restoration of natural areas to ensure their use but also the conservation of biological and cultural diversity.

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Chapter 9
The Conservation and Restoration of the Mexican Islands, a Successful Comprehensive and Collaborative Approach Relevant for Global Biodiversity

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Abstract Islands are biodiversity hotspots that offer unique opportunities for applied restoration techniques that have proven to bring inspiring outcomes. The trajectory of island restoration in Mexico is full of positive results that include (1) the removal of 60 invasive mammal populations from 39 islands, (2) the identification of conservation and restoration priorities, (3) the active restoration of seabird breeding colonies through avant-garde social attraction techniques, (4) the active restoration of integrated plant communities focusing on a landscape level, (5) applied research and science-based decision-making for the management of invasive alien species, (6) the legal protection of all Mexican islands, and (7) biosecurity and environmental learning programs to ensure outcomes are long lasting. Still, there are many complex challenges to face in order to achieve the goal of having all Mexican islands free of invasive mammals by 2030.

Keywords Islands · Mexico · Restoration · Eradication · Biosecurity · Seabirds

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9.1 Islands: Hotspots for Global Biodiversity

Islands worldwide are strongholds of our shared natural heritage. Despite comprising only 5.5% of the world's land surface, they are home to one fifth of all plant, reptile, and bird species (Whittaker and Fernández-Palacios 2007). Due to their isolation, they have allowed evolution to develop unusual characteristics, such as flightless birds, gigantism, or dwarfism (Mulongoy et al. 2006). Therefore, these ecosystems have particularly high endemism richness, harboring 9.5 and 8.1 times more endemic plants and vertebrate species, respectively, than their continental counterparts (Kier et al. 2009). They are particularly important for seabirds as 17% of all bird species are confined to oceanic islands (Croxall et al. 2012).

These make island ecosystems vital for biodiversity conservation. They are crucial spaces for many species that depend on them for refuge, breeding, and rearing their young (Cushman 1995). They also perform complex ecosystem services, such as supporting nutrient cycling, soil and sand formation, as the water that surrounds them are rich in biological productivity, thus supplying great economic and social worth (Aguirre-Muñoz et al. 2011a).

9.2 The Islands of Mexico: Both Spectacular and Fragile

Distributed throughout all of the Mexican seas, there are 4,111 islands, islets, and keys, comprising a landmass of 8,025.2 km^2. Due to Mexico's location, their islands are extraordinarily diverse, ranging from the Nearctic to the Neotropical biogeographic zones. Islands can be divided into semiarid in the Eastern Pacific Ocean influenced by the California Current; desertic in the *sui generis* Gulf of California; and semitropical and tropical in the tropical Pacific Ocean, the Gulf of Mexico, and the Caribbean (Aguirre-Muñoz et al. 2016).

Out of these thousands of insular elements, the 65 "biggest" islands that include Tiburón, Ángel de la Guarda, Cozumel, Cedros, and Guadalupe—all over 1,000 ha—contribute to 87.6% of the country's total insular surface. These ecosystems harbor a disproportionate amount of biodiversity. They hold, at least, 8% of all Mexican vertebrate species. The islands with higher species richness are Clarión (646 marine and 343 terrestrial), Cozumel (487 and 437), Cayo Centro in Banco Chinchorro (574 and 174), Arrecife Alacranes (695 and 162), and Espíritu Santo (428 and 241) (CONABIO 2007).

As for endemism, 3.7% of the country's unique species live on islands, which harbor 9 times more endemic species per square kilometer than mainland (Aguirre-Muñoz et al. 2016). The islands with the highest strict endemism richness are Guadalupe (36 species), Tiburón (19), Espíritu Santo (14), Cerralvo (13), and Santa Catalina or Catalana (11) (CONABIO 2007).

Moreover, islands are crucial to migratory species being part of ecoregions. They are stepping stones that transcend national borders. For example, the islands in the

Pacific off the Baja California Peninsula harbor key breeding populations of widely distributed seabirds—from the Aleutians and the Bering Sea to the Mexican Pacific. One third of all known seabird species (115 out of 346) are found in the Mexican islands, ranking Mexico as the third most diverse country for this fragile group, as well as for the number of endemic seabirds (Croxall et al. 2012).

Due to the location of its outlying islands, such as Guadalupe and the Revillagigedo Archipelago, Mexico has a vast exclusive economic zone of 3.1 million square kilometers, ranking 13th in the world (INEGI 2015). Therefore, islands are key to exercise Mexico's national sovereignty, with their natural resources providing a great wealth to the country. Regarding human population, 73 islands are home to 294,710 people. In the Gulf of Mexico and the Caribbean, Del Carmen (169,725 inhabitants), Cozumel (79,522), and Mujeres (12,646) gather 89% of all the island human population. These islands shelter a high population density, even higher than the average for the country of 61 inhabitants per square kilometer (INEGI 2013, 2016; Aguirre-Muñoz et al. 2016).

The Mexican government has acknowledged the importance of the country's islands by protecting them. Setting a benchmark for island conservation in Mexico, after 13 years of lobbying, in 2016 the "Baja California Pacific Islands Biosphere Reserve" was created (DOF 2016; Box 9.1). Now, all of the Mexican islands are part of the protected area system, under management by the National Commission for Natural Protected Areas (CONANP) (Aguirre-Muñoz and Méndez-Sánchez 2017).

Box 9.1: "The Baja California Pacific Islands Biosphere Reserve: Far Beyond a Paper Park"

The roots for this Biosphere Reserve come from the organized civil society; both the productive and environmental sector worked together with CONANP on its design, promotion, and establishment. For 13 years, the Mexican non-profit conservation organization Grupo de Ecología y Conservación de Islas, A.C. (GECI), together with artisanal fishing cooperatives—particularly the Pescadores Nacionales de Abulón (PNA)—represented by their regional federation FEDECOOP and backed by the Senate and the Congress, requested the country's federal government to protect the islands off the Baja California Peninsula and their surrounding waters. Finally, during the United Nations Biodiversity Conference held in Cancun, Quintana Roo, in December 2016, Mexico's President announced its creation (Dibble 2016). The Biosphere Reserve consists of 21 islands and 92 islets located within the California Current. It comprises 68,796 ha of land surface and 1,092,651.23 ha of ocean waters.

The overarching rationale behind this Reserve has always been the protection of the extraordinary biodiversity of these islands, as well as securing the livelihoods of local communities (i.e., fishing cooperatives) that rely on sustainable artisanal fisheries, particularly of lobster and abalone. This internationally recognized category of protected area seeks to harmonize the sustainable use of resources by local communities with the effective conservation of biodiversity. This decree validates and embraces the trajectory and ongoing comprehensive conservation and tangible restoration actions that have been implemented on these islands for the past 15 years. Throughout this time, GECI has been tackling threats that span from invasive mammals and guano mining to development projects such as the potential installation of a liquefied natural gas regasification plant in Coronado Sur Island (Aguirre-Muñoz et al. 2011a). Almost all of the islands within the Reserve are free of invasive mammals due to GECI's ongoing restoration program. Therefore, other important projects can be implemented. GECI, in partnership with NOAA, USFWS, Cornell Lab of Ornithology, the Audubon Society and support from the Alianza World Wildlife Fund Mexico – Fundacion Carlos Slim and the Mexican Fund for the Conservation of Nature (FMCN) from Mexico, is implementing a long-term seabird restoration program that includes habitat restoration and seabird colonies restoration using social attraction techniques.

Consolidating the ongoing tangible results is of vital importance. Accumulating more conservation and sustainable management results is important to reinforce the continuation of long-term funding for restoration projects and strengthening the relationship between GECI, local communities, and authorities. By working hand in hand, we will ensure an island legacy for generations to enjoy.

Unfortunately, islands worldwide are suffering a disproportionate rate of extinctions (Groombridge and Jenkins 2002; Boyd et al. 2008). Eighty-eight percent of the vertebrate species that have gone extinct in Mexico are island endemics (Aguirre-Muñoz et al. 2016). Invasive alien species (IAS) are by far the main driver of extinction on islands (Simberloff et al. 2013; Reaser et al. 2007); and Mexican Islands are not the exception, where 17 subspecies have become extinct, meaning 76% of the extinctions have been caused by invasive mammals on islands (Aguirre-Muñoz et al. 2011b). Invasive mammals such as rodents, cats, and herbivores are the most harmful and widespread species (Doherty et al. 2016; Russell 2011). Direct impacts are predation, competition, habitat destruction, physical and chemical damage to soils, and erosion. Indirect impacts are introduction of seeds, seedlings, diseases, parasites, and general unbalance of the trophic web. They cause dramatic impacts on communities and ecosystems (Clout and Williams 2009; Lovei and Lewinsohn 2012). Invasive alien species affect negatively on an ecological level but also on the economic, health, and well-being aspects of local communities (Early et al. 2016; Reaser et al. 2007).

Fortunately, islands have also proven to provide amazing opportunities for restoration and biodiversity conservation (Veitch and Clout 2002). The Grupo de

Ecología y Conservación de Islas, A.C. (GECI), is a Mexican nonprofit, devoted to the comprehensive restoration of islands, through a transdisciplinary approach and science-based management. With a successful 20-year trajectory on island restoration, GECI, in close collaboration with the Mexican government, has developed a National Island Restoration Program, which now boasts tangible results.

9.3 A National Program for Island Restoration

9.3.1 Science-Based Management

When an ecosystem has been altered and has lost its capacity to bounce back through its own resilience mechanisms, thoughtful intervention and ecological restoration are needed (Jorgensen 2013). There are several instruments for restoration; however, the management of IAS—either control or eradication—is recognized as the most efficient, particularly when endangered species are involved (Mulder et al. 2011; Veitch et al. 2011). Controlling a population of an IAS implies keeping the target population with a low density through a sustained effort over a long period. On the other hand, eradicating means the complete removal of an IAS population and concentrates all efforts over a defined period of time (Veitch and Clout 2002). The concept of eradicating mammals from islands was born and developed in New Zealand, a country that is a worldwide leader in island restoration (Towns et al. 2013).

For the past two decades, GECI has been steadily working toward the conservation of the Mexican islands through restoration actions. The first step is the eradication of IAS. All projects have been executed in close collaboration with the federal government, particularly CONANP, the National Commission for the Knowledge and Use of Biodiversity (CONABIO), the National Institute for Ecology and Climate Change (INECC), the Secretary of the Environment and Natural Resources (SEMARNAT), and the Secretariat of the Interior (SEGOB). Of great importance is the support given by the Mexican Navy (SEMAR), which continually allocates the use of specialized vessels, equipped with helicopter pads, and lodging, for use during eradication campaigns or movements to remote islands. Also significant has been the participation of academic institutions, research centers, local communities, fishing cooperatives, other civil society organizations, and national and international donors from the public and private sector (Aguirre-Muñoz et al. 2011a).

For two decades, GECI has gathered experience and scaled up from relatively simple and straightforward eradications to complex scenarios that have required state-of-the-art techniques and innovation. According to Aguirre-Muñoz et al. (2016), there are four stages vital for successful restoration actions:

1. Diagnosis–prognosis: Developing baseline information to identify restoration priorities and plan actions according to priorities, biodiversity values, and the feasibility of successful intervention.

2. Systematic monitoring: Once the areas of research opportunity have been recognized, systematic monitoring of indicator species must be performed to make informed decisions on which restoration actions to implement, whether control or eradication of one or several IAS, as well as other actions such as habitat improvement or social attraction techniques for restoring seabird colonies.
3. Project execution: Fieldwork is the core of tangible restoration actions. However, for conservation gains to endure, they must be accompanied by an environmental learning strategy, where local community involvement and island biosecurity are key components.
4. Ecosystem recovery assessment: After removing the threat, systematic monitoring of indicator species must continue in order to document changes in the island's native species and identify if there is need for other restoration actions.

9.3.2 Advances on Island Restoration

Up to April 2018, 60 populations of invasive mammals have been removed from 39 islands (Table 9.1). Out of these 39 islands, 30 are now completely free of invasive mammals (Fig. 9.1). Eradication techniques have evolved from traditional (e.g., trapping and hunting) to state of the art, such as aerial dispersal of ad hoc designed bait, aerial hunting, and telemetry. Size and complexity of the islands have also increased (Fig. 9.2).

Table 9.1 Successful invasive mammal populations eradicated from the Mexican islands up to 2018

Island	Area (ha)	Invasive mammal removed	Eradication date	Eradication technique	Invasive mammal still present
Pacific Ocean					
Asunción	41	Cat	1995	Trapping	None
Clarión	1,958	Sheep, pig	2002	Hunting	Rabbit
Coronado Norte	37	Cat	1995–1996	Trapping	None
Coronado Sur	126	Cat, goat, donkey	2003	Trapping, hunting	House mouse
Guadalupe	24,171	Rabbit, donkey	2002	Live removal	Cat[a] and House mouse
		Horse	2004	Live removal	
		Goat	2003–2006	Live removal, trapping, hunting, telemetry	
		Dog	2007	Live removal, trapping, hunting	

(continued)

Table 9.1 (continued)

Island	Area (ha)	Invasive mammal removed	Eradication date	Eradication technique	Invasive mammal still present
Natividad	736	Goat, sheep	1997	Live removal	Antelope squirrel
		Cat	1998–2000	Trapping, hunting, live removal	
		Dog	2001	Live removal	
San Benito Este	146	Rabbit	1999	Trapping, hunting	None
San Benito Medio	45	Rabbit	1998	Trapping, hunting	None
San Benito Oeste	400	Rabbit, goat	1998	Trapping, hunting	None
		Donkey	2005	Live removal	
		Cactus mouse	2013	Aerial bait dispersal	
San Jerónimo	48	Cat	1999	Trapping, hunting	None
San Martín	265	Cat	1999	Trapping, hunting	None
San Roque	35	Cat	1995	Trapping	None
		Black rat	1995	Bait stations	
Socorro	13,033	Sheep	2009–2010	Hunting, telemetry	Cat[a]
Todos Santos Norte	34	Cat, rabbit	1999–2000	Trapping, hunting	None
		Donkey	2004	Live removal	
Todos Santos Sur	89	Cat	1997–1998/1999/2004	Trapping, hunting	None
		Rabbit	1997	Trapping, hunting	
Gulf of California					
Coronados	715	Cat	1998–1999	Trapping	None
Danzante	412	Cat	2000	Trapping	None
Espíritu Santo	7991	Cat	2016	Trapping, hunting	Goat[a]
Estanque	82	Cat	1999	Trapping, hunting	None
Farallón de San Ignacio	17	Black rat	2007	Aerial bait dispersal	None
Isabel	82	Cat[b]	1995–1998	Trapping, hunting, bait stations	None
		Black rat	2009	Aerial bait dispersal	
Mejía	245	Cat	1999–2001	Trapping, hunting	Black rat, house mouse
Montserrat	1886	Cat	2000–2001/2003	Trapping, hunting	None
Partida Sur	1533	Cat	2000	Live removal	None
Rasa[b]	57	Black rat, house mouse	1995–1996	Bait stations	None
Redonda	23	Cat	2012–2014	Trapping, hunting	None
San Jorge Este	9	Black rat	2000–2002	Bait stations	None

(continued)

Table 9.1 (continued)

Island	Area (ha)	Invasive mammal removed	Eradication date	Eradication technique	Invasive mammal still present
San Jorge Medio	41	Black rat	2000–2002	Bait stations	None
San Jorge Oeste	7	Black rat	2000–2002	Bait stations	None
San Francisquito	374	Cat	2000	Trapping, hunting	None
		Goat	1999	Hunting	
San Pedro Mártir	267	Black rat	2007	Aerial bait dispersal	None
Santa Catalina (Catalana)	3890	Cat	2000–2004	Trapping, hunting	Deer mouse
Venados	54	Goat	2016	Trapping	Coatimundi
Gulf of Mexico and Caribbean					
Cayo Norte Mayor	29	Black rat	2012	Aerial bait dispersal	None
Cayo Norte Menor	15	Black rat	2012	Aerial bait dispersal	None
Cayo Centro	539	Cat	2014	Trapping	None
		Black rat	2015	Aerial and manual bait dispersal	
Muertos	16	House mouse	2011	Manual bait dispersal	None
Pérez	11	Black rat	2011	Manual bait dispersal	None
Pájaros	2	House mouse	2011	Manual bait dispersal	None
Total	59,422				

Source: Updated from Aguirre-Muñoz et al. (2016)
[a]Eradication in progress
[b]Eradication executed by UNAM

Particularly for invasive rodents, experience has allowed us to learn from treating small desert islands (<50 ha) to tropical and wet archipelagos (>500 ha) (Aguirre-Muñoz et al. 2016). In 2015, the successful black rat (*Rattus rattus*) eradication from Cayo Centro (539 ha), a mangrove-dominated island part of the Banco Chinchorro Biosphere Reserve, was a worldwide benchmark for tropical island eradication projects (Samaniego-Herrera et al. 2017). Experience has also led to innovation, such as improving the efficiency of aerial rodent eradication through the development of a mathematically founded new tool, the *Numerical Estimation of Rodenticide Dispersal* (NERD), which performs calculations with increased accuracy, displaying results almost in real time, allowing instant identification of bait gaps that could cause failure of eradication (Rojas-Mayoral et al. in press).

As for feral cats, two ambitious ongoing eradication projects will provide lessons to move forward to even bigger islands. The eradication of feral cats from Socorro Island (13,033 ha), in the remote Revillagigedo Archipelago, currently on the removal

Fig. 9.1 Successful, in progress, and pending invasive mammal population eradications in the Mexican islands, up to April 2018

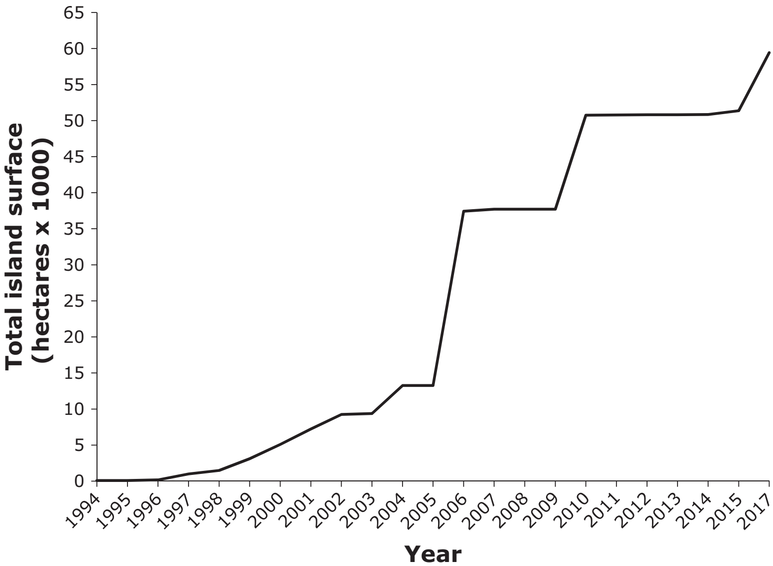

Fig. 9.2 Time series of total insular surface in way of restoration from 1994 to 2017 (Updated from Aguirre-Muñoz et al. 2016)

of the last remaining cats, will be the biggest island in the world where cats have been eradicated by trapping and hunting, without the use of any toxicant (Ortiz-Alcaraz et al. 2017). Moreover, in 2017 the eradication of cats on Guadalupe Island (24,171 ha) started, with the goal to completely remove them from the island by 2020.

9.3.3 Commitments of Future Eradications

Mexico's trajectory on island restoration moves forward at a steady pace. Mexico's goal is to have all islands free of invasive mammals by 2030, as pledged to the IUCN's Honolulu Challenge on Invasive Alien Species, which called for bold action on the most prominent driver of extinctions (IUCN 2018).

The eradication of the remaining 83 invasive mammal populations from 34 islands is in various stages. According to a multicriteria decision analysis (Latofski-Robles et al. 2014), the islands ranked as priority where eradication is feasible are Socorro, Espíritu Santo, María Cleofas, and María Magdalena. By eradicating these 11 invasive mammal populations, a further 35,813 ha would be treated thus reducing risk of extinction of 80 endemic species (Aguirre-Muñoz et al. 2016).

In order to protect restored islands, as well as the millionaire investment on conservation projects, island biosecurity—the measures and actions to prevent IAS introductions—has become a transversal topic on all restoration projects to ensure long-lasting outcomes. Island biosecurity has three components: (1) prevention, creating awareness and involving local communities to become active participants so that islands remain free of IAS; (2) early detection, keeping active and passive surveillance systems in order to detect any incursion before it can become established; and (3) rapid response, swiftly eliminating any individual detected and assessing the status of an IAS on an area (Russell et al. 2008).

Therefore, a National Island Biosecurity Program is currently being developed. In close collaboration with CONABIO and CONANP and with funding from the Global Environment Facility (GEF) through the United Nations Development Program (UNDP), GECI is formulating—through a participative process—site-specific ad hoc biosecurity protocols. This bottom-up approach has led to more involvement, understanding, and vigilance from local communities and island users (Latofski-Robles et al. in press). Biosecurity and environmental learning campaigns with local communities have already proven to be vital for islands to remain free of invasive mammals. In Perez Island, part of the Arrecife Alacranes National Park, the incursion of a black rat was detected right on time and eliminated, thanks to the biosecurity protocol established with the local CONANP office. Thanks to a permanent specific biosecurity protocol and to communication with authorities the island was protected against reinvasion (Latofski-Robles et al. 2017).

Prevention is the cornerstone of island biosecurity. It is by far the most cost-effective method toward long-term conservation gains. It is mostly done in the continent at docks, marinas, warehouses, etc. All stakeholders must be involved, from the authorities who divulge prevention measures and enforces them, to local communities who must adopt preventive practices whenever they move between islands and mainland. Everyone must comply if we are to keep islands free from IAS forever.

9.4 Tangible Outcomes from Restoration Actions

The island ecosystem's recovery has been remarkable. The documented results from applied restoration actions are noticeable and relevant. Due to the removal of invasive mammals, at least 147 endemic taxa of mammal, reptile, birds, and plant species have been protected. Furthermore, 227 seabird breeding colonies, highly vulnerable to rats and cats, are recovering (Aguirre-Muñoz et al. 2016). Systematic post-eradication monitoring has revealed positive outcomes, such as new record of plants believed to be extinct, like the *Satureja palmeri* on Guadalupe Island which reappeared after goat eradication (Junak et al. 2005). On Isabel Island, invertebrates from the intertidal zone show positive effects after black rat eradication (Samaniego-Herrera and Bedolla-Guzman 2012). On Socorro Island, recovery of plant communities and soil resulted on 11% increase in plant coverage after sheep eradication (Ortiz-Alcaraz et al. 2016). On San Pedro Mártir Island, red-billed tropic bird nests increased by 60%, as well as their reproductive success (Aguirre-Muñoz et al. 2011b).

9.5 A National Seabird Restoration Program

On the Baja California Pacific Islands, at least 28 seabird populations were extirpated, and several were diminished by invasive mammals, human disturbance, and contaminants (Bedolla-Guzmán et al. in press). As a following step after removing invasive mammals, since 2008 GECI began a seabird restoration program. The program focuses on eight groups of islands and includes monitoring the natural recovery of seabird populations post-eradication of invasive mammals, removal of introduced vegetation for habitat enhancement, reducing human disturbance, interdisciplinary research, environmental learning and biosecurity with local communities. Furthermore, the program also implements avant-garde social attraction techniques systematically, for the first time in Latin America (Aguirre-Muñoz et al. 2016). Social attraction consists on recreating artificial colonies. Using decoys, building artificial nest boxes, and playing vocalizations on sound systems, seabirds are lured to visit the island. Eventually, birds recognize the island as a safe place to nest and start building new colonies (Jones and Kress 2012).

The program has already achieved valuable results. In total, 22 recolonizations have been recorded, for some of which social attraction techniques were key. For example, the royal tern (*Thalasseus maximus*) was last recorded in San Roque Island 90 years ago. After 8 years of implementing social attraction techniques, in 2017, 736 breeding pairs were recorded within an artificial colony. Furthermore, we have recorded 12 new colonies of several species established on these islands, which recolonized naturally. One remarkable example is the Ashy Storm-Petrel (*Oceanodroma homochroa*), which was recorded nesting in Todos Santos Sur Island. This new colony represents the southernmost breeding range of this species to date (Bedolla-Guzmán et al. in press).

9.6 A Comprehensive Reforestation Project

Guadalupe Island is now on the front line of a state-of-the-art, integrative, in situ reforestation project. In close collaboration with the federal government through the National Forestry Commission (CONAFOR) and CONANP, as well as support from SEMAR, the project includes production of native and endemic plants, such as the endangered Guadalupe cypress (*Cupressus guadalupensis*), the endemic *Pinus radiata* var. *binata*, and the island oak (*Quercus tomentella*) on a nursery on the island. The project seeks to bring an integrated vision to restore the vegetation communities as an alternative to traditional reforestation schemes focusing only in one tree species. It also includes soil restoration, removing fuel material, and maintaining firebreaks (Aguirre-Muñoz et al. 2017).

9.7 A Need for Island Conservation Public Policies

Mexico has two National Strategies that pave the way and set the course for island restoration. The first is the National Strategy on Invasive Alien Species, published in 2010, which is currently being implemented through funds from the Global Environment Facility. The second is the National Strategy for the Conservation and Sustainable Development of the Mexican Islands (2012), which establishes a route and long-term objectives, incorporating a vision for a future where all island-related activities are executed sustainably and with best practices, including fishing, using alternative energies, and alternative tourism (Aguirre-Muñoz et al. 2017).

One of the greatest obstacles of managing IAS is the lack of regulations on animal sacrifice as ecological contingency measure. There are no specific norms for the sacrifice of feral species as restoration methods, or norms that consider eradication of IAS as priority actions for conservation, which they unequivocally are. However, despite this lack of regulation, Mexico applies the highest standards for eradication activities (Aguirre-Muñoz et al. 2017).

Also urgent is the regulation and implementation of island biosecurity measures to ensure long-term results. Adding the concept of island biosecurity in the existing legal framework is crucial in order for each corresponding authority to regulate and assess that people comply with designated biosecurity measures and estipulate and apply sanctions if it is needed (Aguirre-Muñoz et al. 2017).

9.8 Conclusion

The Mexican islands give us an exceptional opportunity, where conservation and restoration efforts result in significant benefits for our shared natural heritage, with a high return on investment. However, to overcome the restoration challenges and complexities that we have, we must continue to build local capacities and consolidate the now very specialized human resources in order to achieve the goal of removing all invasive mammals from islands by 2030.

Several elements have been crucial to the successful trajectory of island restoration in Mexico:

- Collaborative work and building trust: restoration projects are complex and must involve a wide array of stakeholders. National and international collaboration has been important, both for scientific research as for sustained funding. Close partnership with the federal government has helped shape the island conservation agenda, as well as promote governance and participation in creating public policies that will benefit biodiversity and local communities. Finally, working closely with fishing cooperatives and local communities is of the utmost importance to implement island biosecurity measures and achieve long-lasting conservation goals.
- Applied research: there are plenty of knowledge gaps when it comes to island ecology and biodiversity, which translates to opportunities for scientific research of great value, especially because this knowledge will be used for science-based decision-making and management, and guides long-term conservation strategies.
- Systematic planning: setting priorities is fundamental to maximize the efficiency of limited conservation funding. An interdisciplinary perspective is needed to strengthen restoration work on islands.

9.9 Recommendations

- The National Island Biosecurity Program must be institutionally strengthened and further developed in order to prevent reintroductions or new introductions on islands free of invasive alien species.
- The National Strategy on Conservation and Sustainable Development of the Mexican Islands should be revised and updated, in the same participative manner as it was formulated.
- Sustained and long-term funding is vital to keep the current trajectory on island conservation, as well as the positive outcomes.

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Chapter 10
Successful Experiences in Promoting Scientific Research in Mexican Conservation Biology

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Abstract This chapter describes two private projects that promote and support scientific research in conservation biology in Mexico. The first project describes 10 years of experiences of a program known as "Por Amor al Planeta," funded by Volkswagen Mexico, which recognizes the efforts of Mexican scientific researchers in the field of biological conservation in Mexico, specifically in natural protected areas. The second project is based on the Ecological Reserve "El Edén" (located north of Quintana Roo, México). It explains more than 20 years of experiences of a private reserve dedicated to supporting and promoting scientific research in biodiversity conservation and management.

Keywords Biodiversity · Conservation · Awards · Eden · Reserve · Research

10.1 Introduction

One central problem of biodiversity conservation in Mexico today is that although it seems that we all agree on its importance and the urgency to protect it, there are very few places that have been studied in depth. Scientific research in conservation biology is scarce and is badly needed. As Watson and Venter wrote in their recently publication, "Conservation biology is the study of attempts to protect and preserve biodiversity. It focuses on both the biological and social factors that affect the success of conservation efforts and on determining ecosystems and species whose

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conservation is a high priority" (Watson and Venter 2017). We need to know what are the best approaches for conservation to confront the major well-known threats that menace our planet's biodiversity: climate change, tropical deforestation, habitat loss, biological extinctions, and pollution.

Scientific research is not a priority action in the calls for conservation of nature. The principal global initiative to confront this problem has been to create more areas protected from human activity as insurance for the future. According to the National Commission of Protected Areas of Mexico (CONANP 2017), protected areas are portions of land or water in the country representing various ecosystems, where the original environment has not been essentially altered and which produce environmental benefits increasingly recognized and valued. However, the information in which to base the size, number of areas, and location needed to protect high diversity sites is scarce. Most of the new protected areas are selected by educated guesses of local experts rather than in hard data generated by research. An incomplete list of the best-known fauna (mostly vertebrates) and flora (mainly flowering plants) usually is used as the "scientific" validation for the establishment of the reserve. As Bernard Williams once said, "A natural park is not nature, but a park; a wilderness that is preserved is a definite, delimited, wilderness. The paradox is that we must use our power to preserve a sense of what is not in our power" (Williams 1995).

The explanation for why this has not been done in developing countries is that there are not enough scientists available to do the needed in-depth studies in protected spaces. Conservation organizations and funding agencies have given high priority to short-term studies that have low cost, which unfortunately do not provide the needed information. Long-term scientific studies to address the badly needed problems of biodiversity conservation and management seem to have been postponed permanently.

In contrast with this fact, we have the permanent discussion that the reason why we want to conserve biodiversity is because of the potential value it has for humankind. Here we have a painful paradox. We are protecting a biodiversity that we do not know and we are not planning to study, using the reason of its usefulness. How can anyone know if something is useful or not if we do not know we have it?

10.1.1 Problem Description

The enormous transformation to which our planet has been subjected has brought the dramatic loss of biological resources. The current challenge is to assess this problem in various parts of the world and find ways to stop and reverse it. This can only be done with scientific information produced throughout the world.

Scientific research in Mexico on biological conservation does not have the priority it should have. The country invests a good amount of resources in the creation of protected areas but very little on scientific research to explore the best approaches for the protection of rare species and ecosystems.

The two approaches we describe in this chapter are addressing the importance to promote scientific research in conservation biology and biodiversity conservation.

The Volkswagen Award, “Por Amor al Planeta” (For the Love of the Planet), was created to recognize a distinguished group of Mexican scientists for their outstanding scientific contributions to biological conservation in Mexico, as well as give support for research projects in natural protected areas (NPAs). “El Edén” Ecological Reserve (EEER) is a private NPA dedicated to doing and promoting scientific research in a dry tropical forest region and wetland site in the Mayan region of Mexico.

10.2 Por Amor al Planeta: Project of Volkswagen Mexico

The natural legacy in Mexico is a privilege that must be recognized as an important element for the sustainable future of societies. Thus, the work of protecting this natural capital concerns not only a few sectors of society.

Volkswagen Mexico (VWM) encourages the vision shared by different sectors of Mexican society about the urgent protection and study of nature. VWM believes that the responsibility with biodiversity is a principle and to participate in the search of solutions to the environmental crisis is a priority. Therefore, action was taken to contribute to the conservation, restoration, and recovery of nature, through the establishment of the “Por Amor al Planeta” program.

The program consisted of two awards: Award for Scientific Research in Biological Conservation and Support for a Research Project in an NPA, which will be described in detail. The first edition of the program was in 2006 and the last one in 2015, 10 years promoting scientific research in Mexico.

One essential part of the program was the selection of the jury, which was composed mainly of people who have a recognized and proven trajectory nationally and internationally in different aspects of nature conservation. In the first edition of the program, the jury was consisted by; a representative of the federal government (Ernesto Enkerlin Hoeflich, PhD, member of the National Commission of Protected Natural Areas, CONANP), a representative of the Organized Civil Society (OCS) (Ing. Guillermo Barroso Montull, president of a Mexican environmental conservation group, PRONATURA AC), four researchers with proven trajectory both nationally and internationally (Rodolfo Dirzo, PhD; Exequiel Ezcurra, PhD; Otto Solbrig, PhD; and Ernesto Rodríguez Luna, PhD), and, finally, three members of VWM (Francisco Bada Sanz, Thomas Karig, and Raúl Rodríguez).

In the second edition, Otto Solbrig, PhD, left the jury because the jury meetings scheduled for the second edition were not compatible with his agenda. The other jury members invited Gonzalo Halffter Salas, PhD, (winner of the first edition of the program) to participate as a member of the jury for the second edition. For the third edition, Gonzalo Halffter Salas, PhD, left the jury for health reasons, and again by consensus of the other members of the jury, it was decided to invite again the winner of the second edition, so Gerardo Ceballos González, PhD, joined the jury. For the next jury meeting (fourth edition), the winner of the third edition was also included, so Rodrigo Medellín Legorreta, PhD, joined the jury, giving a total of ten members. All members of the jury (Fig. 10.1) confirmed their participation year after year until the last edition (2015) of the VWM program.

Fig. 10.1 Members of the jury of ¨Por Amor al Planeta¨ program and staff of VWM. (Photograph by ARGO Environmental Consulting Firm)

It should be noted that, since the beginning and throughout the 10 years of the program, the figures of president of the jury and representative of the OCS remained permanently occupied by Mr. Thomas Karig (vice president of corporate relations of VWM) and Mr. Guillermo Barroso Montull.

10.2.1 Award for Scientific Research in Biological Conservation

The award was intended to recognize researchers or research groups with a distinguished career within the area of biological conservation in Mexico, whose contributions influenced the establishment of current or potential policies for the conservation of nature. The award promoted the formation of new generations of researchers and the dissemination of their work toward society.

Trajectory, scientific relevance, social impact, replicability, and commitment to the training of new scientists were the main aspects that the jury members evaluated to make their final decision.

More specifically the following criteria were taken into consideration to choose the winner of each of the ten editions of the program.

- That the project's active researchers or groups of researchers were using an NPA as a fundamental site for the development of their work and studies.
- That the researchers had a distinguished career and proven experience in scientific research for at least 10 years.
- That, through the award, the scientist's full trajectory was recognized in order to stimulate long-term productivity as well as creativity in their work.
- That the work done by the researcher showed a transcendental biological, social, and economic impact.
- That the project contained originality, creativity, scope, and degree of innovation of scientific and technological development programs and their impact on the generation of knowledge about biodiversity in Mexico.
- That the results of their work can be applied in similar circumstances in the protection, management, and restoration, as well as the sustainable management of the natural resources of different regions of the country.
- That the information derived from their research allowed the definition of better biological governmental conservation policies.
- That the researcher or research group was forming new generations of researchers on conservation biology.
- That the applicant had carried out important actions to inform the general public on the findings and importance of the research done.

10.2.1.1 Winners

First Edition (2006): Gonzalo Halffter Salas, PhD.

Halffter Salas is a biologist of the National School of Biological Sciences of the National Polytechnic Institute. He has been the founder and director general of the Institute of Ecology, A.C. He was the director of the Museum of Natural History of Mexico City.

He has published more than 240 scientific articles and 55 books or book chapters INECOL (2017). His diverse contributions to the areas of animal behavior, biogeography, biodiversity, and the conservation of natural resources make him one of the most important Mexican scientists. He is considered as one of the pioneers in the establishment of new concepts that influenced the notion of sustainability and the development of biodiversity conservation policies, and he contributed to the creation of several biosphere reserves of Mexico.

Three of his most important and recent publications in conservation biology are:

1. Escobar, F., G. Halffter and L. Arellano. 2007. From forest to pasture: An evaluation of the influence of environment and biogeography on the structure of dung beetle (Scarabaeinae) assemblage along three altitudinal gradients in the Neotropical Region. *Ecography* 30: 193–208.

2. Halffter, G. 2005. Towards a culture of biodiversity conservation. *Acta Zoológica Mexicana (n.s.)* 21 (2): 133–153.
3. Padilla, D.N. & G. Halffter. 2006. Biogeography of the areas and Canthonini (Coleoptera: Scarabaeinae) of dry tropical forests in Mesoamerica and Colombia. *Acta Zoológica Mexicana (n.s.).* 23 (1): 73–108.

Second Edition (2007): Gerardo Ceballos González, PhD.

Professor Ceballos González is a highly distinguished and globally recognized ecologist and conservation biologist. He is a world leader in the evaluation and design of conservation strategies for both endangered species and threatened ecosystems. He has earned this distinction because of his significant contributions to science and conservation efforts, including but not limited to his (1) pioneering and extraordinarily diverse ecological and conservation research, (2) exceptional efforts to use ecological knowledge to address crucial societal issues, (3) building of bridges between ecology and conservation in order to humanely implement viable options to attain paths to ecological sustainability, and (4) untiring efforts to increase the ecological literacy of the general public. Notable among his many conservation achievements is his success in proposing and facilitating the establishment of more than 20 protected areas that cover almost 2% (4 million hectares) of the Mexican land mass. These reserves protect thousands of plant and animal species, including an estimated 20% of all endangered vertebrate species.

His research and advocacy was instrumental in the 1994 adoption of the Mexican Law for Endangered Species Protection, which now protects more than 4000 endangered species; this is one of his most long-lasting contributions. He is the author of 48 books and more than 500 scientific and outreach articles of conservation biology, ecology, ecological applications, and biological conservation. A lot of his artiles are published in scientific journals such as Science, PNAS and PLoS One.

Three of his most important and recent publications in conservation biology are:

1. Ceballos, G., P. R. Ehrlich and R. Dirzo. 2017. Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. *Proceedings of the National Academy of Sciences*, *114*(30), E6089–E6096.
2. Ceballos, G., A. Barnosky, A. García, R.M. Pringle, T.M. Palmer and P.R. Ehrlich. 2015. Accelerated Modern Human Induced Species Losses: Entering the Sixth Mass Extinction. *Science Advances.* 1:e1400253.
3. Ceballos, G., P.R. Ehrlich and A.H. Ehrlich. 2014. *Annihilation of Nature: Human Extermination of Birds and Mammals.* John Hopkins Press, Baltimore.

Third Edition (2008): Rodrigo A. Medellín Legorreta, PhD.

Medellín Legorreta (Fig. 10.2) is a senior professor of ecology at the Institute of Ecology, University of Mexico. He has dedicated his life to the study of the ecology and conservation of mammals in Mexico and elsewhere for over 30 years. Working from rainforests to deserts to montane forests, he uses community ecology, plant-animal interactions, population biology, and molecular ecology to solve conservation problems.

Fig. 10.2 Dr. Medellín working with bats FWS U.S. Fish and Wildlife Service (2015). (Photo by Marina Rivero)

He has over 190 publications including over 90 papers in peer-reviewed journals and over 50 books and book chapters on bat ecology and conservation, jaguar conservation and recovery, mammal diversity analyses, and conservation of large mammals. Medellín Legorreta was the head of the Wildlife Department of the Mexican federal government in 1995–1996, the founder and director of the Program for the Conservation of Bats of Mexico, and the founding director of the Latin American Network for Bat Conservation RELCOM. Rodrigo is the co-chair of the Bat Specialists Group of IUCN. He co-coordinated Mexico's first National Jaguar Census, CENJAGUAR.

He has taught conservation biology and community ecology for over 30 years. He is an adjunct professor at Columbia University in New York, Andalucia International University, the University of Arizona, and others. His work studying and protecting mammals has influenced policy and spanned all continents and many countries. Since 2016 he is a member of the Board of Reviewing Editors of Science Magazine. Medellín Legorreta has received various recognitions and awards, including the first-ever Whitley Gold Award from Princess Anne of England again in 2012, the first individual ever to receive two Whitley Awards. In 2014 BBC Natural World produced the multi-awarded film The Bat Man of Mexico (narrated by David Attenborough) covering Rodrigo's work on bats.

Three of his most important and recent publications in conservation biology are:

1. De la Torre, J. A., J. F. Gonzalez Maya, H. Zarza, G. Ceballos and R. A. Medellin. 2017. The jaguar's spots are darker than they appear: assessing the global conservation status of the jaguar *Panthera onca*. *Oryx* 51: DOI: https://doi.org/10.1017/S0030605316001046

2. Frick, W.F., E.F. Baerwald, J.F. Pollock, R.M.R. Barclay, J.A. Szymanski, T.J.Weller, A.L. Russell, S.C. Loeb, R.A. Medellin and L.P. McGuire. 2017. Fatalities at wind turbines may threaten population viability of a migratory bat. *Biological Conservation* 209: 172–177.
3. Wiederholt, R., L. López-Hoffman, C. Svancara, G. McCracken, W. Thogmartin, J. Diffendorfer, K. Bagstad, P. Cryan, A. Russell, D. Semmens and R.A. Medellin. 2015. Optimizing conservation strategies for Mexican free-tailed bats: a population viability and ecosystem services approach. *Biodiversity and Conservation* 24(1): 63–82.

Fourth Edition (2009): Valeria Souza Saldivar, PhD.

Souza Saldivar earned a BS in Biology, MS in Genetics, and PhD in Ecology from the National Autonomous University of Mexico (UNAM). She completed two postdoctoral positions with Richard Lenski on the long-term *E. coli* evolution experiment.

The last years of her investigations have been dedicated to defending and to preserving the Valley of Four Ciénegas in the state of Coahuila, demonstrating and spreading to national and international level the biological, economic, and cultural value of the region. The contributions in the study of conservation and ecology in this area are not only original, innovative, and numerous but also of scientific relevance. Furthermore, she has linked its research with concrete actions for conservation. For the area, she has suggested different strategies for the sustainable management of wetlands. Thanks to her scientific work and dissemination of information, the World Wildlife Foundation (WWF) has declared Four Ciénegas a priority conservation site.

She is currently a senior researcher in the Department of Evolutionary Ecology of the Institute of Ecology of the UNAM. She has published more than 49 research articles in international refereed journals and 12 in national and dissemination journals. She has written seven chapters in books, a coedited book, and ten articles in national magazines.

Three of her most important and recent publications in conservation biology are:

1. Souza V., L. Espinosa-Asuar, A.E. Escalante, L. E. Eguiarte, J. Farmer, L. Forney, L. Lloret, J.M. Rodríguez-Martínez, X. Soberón, R. Dirzo and J. J. Elser. 2006. An endangered oasis of aquatic microbial biodiversity in the Chihuahuan desert. *PNAS* 103(17): 6565–6570.
2. Rusch D.B., A.L. Halpern, G. Sutton, K.B. Heidelberg, S. Williamson et al. 2007. The Sorcerer II Global Ocean Sampling Expedition: Northwest Atlantic through Eastern Tropical Pacific. *PLOS Biology* 5(3): e77. https://doi.org/10.1371/journal.pbio.0050077
3. Hernández A., H.S. Espinosa-Pérez and V. Souza. 2017. Trophic analysis of the fish community in the Ciénega Churince, Cuatro Ciénegas, Coahuila. *PeerJ* 5:e3637.

Fifth Edition (2010): María Enriqueta Velarde González, PhD.

Velarde González is a senior full-time researcher at Instituto de Ciencias Marinas y Pesquerías, Universidad Veracruzana. She has focused her work on seabird ecology, mainly breeding and feeding ecology, as well as conservation and management of insular ecosystems. She has also carry out research about the distribution of seabirds at sea and in the islands of the Gulf of California. One application of her research has been the use of data from her studies of seabird feeding and breeding ecology for the prediction of commercial fisheries.

With Enriqueta Velarde, conservation of the islands of the Gulf of California rose to a new level, with her work published in 1988 titled "Islands of the Gulf of California," formed and led a research group on the Gulf Islands. This publication was a real breakthrough in the conservation of the islands and the entire Gulf. The validity of this study is so great that, almost 20 years later, it formed one of the central elements in the designation of the Gulf of California Islands as a World Heritage Site.

Three of her most important and recent publications in conservation biology are:

1. Bourillón, L., A. Cantú, F. Eccardi, E. Lira, J. Ramírez, E. Velarde and A. Zavala. 1988. *Islas del Golfo de California*. Coedited by la Secretarıa de Gobernación/UNAM, First Edition, Distrito Federal, México. 292 pp.
2. Velarde, E., E. Ezcurra, M.A. Cisneros-Mata and M.F. Lavín. 2004. Seabird ecology, El Niño anomalies, and prediction of sardine fisheries in the Gulf of California. *Ecological Applications* 14: 607–615.
3. Christian, C., D. Ainley, M. Bailey, P. Dayton, J. Hocevar, M. LeVine, J. Nikoloyuk, C. Nouvian, E. Velarde, R. Werner and J. Jacquet. 2013. A review of formal objections to Marine Stewardship Council fisheries certifications. *Biological Conservation* 161: 10–17.

Sixth Edition (2011): Mario González Espinosa, PhD, and Víctor Sánchez-Cordero Dávila, PhD.

In this edition, there was a tie between Mario González Espinosa and Víctor Sánchez-Cordero Dávila.

González Espinosa is an agronomical engineer with a PhD in population biology from the University of Pennsylvania (USA). He is a senior research staff member of El Colegio de la Frontera Sur (ECOSUR), where he has held several academic positions in graduate programs for almost 25 years.

For more than 30 years, his work has focused on understanding the interactions of Mayan rural communities, land-use change, and the provision of ecosystem services in their territories to support their sustainable development in mountain areas of Chiapas and Tabasco. He has dedicated a lot of his time to helping build academic capacities in southern Mexico including graduate education programs, an institutional herbarium, and a productive research group through the training of more than 40 master's and PhD students.

He has over 120 publications including papers and book chapters, and he has been the lead editor of several books. He is a founding member of the "Fundación Internacional para la Restauración de Ecosistemas" operated from Madrid. Besides the “Por Amor al Planeta” Award, in 2013 he received the “Medalla al Mérito Botánico,” the highest distinction awarded by the Botanical Society of Mexico.

Three of his most important and recent publications in conservation biology are:

1. Ramírez-Marcial, N., M. González-Espinosa and G. Williams-Linera. 2001. Anthropogenic disturbance and tree diversity in Montane Rain Forests in Chiapas, Mexico. *Forest Ecology and Management* 154: 311–326.
2. González-Espinosa, M., J.M. Rey-Benayas, N. Ramírez-Marcial, M. A. Huston, and D. Golicher. 2004. Tree diversity in the northern Neotropics: regional patterns in highly diverse Chiapas, Mexico. *Ecography* 27: 741–756.
3. Toledo-Aceves, T., J. A. Meave, M. González-Espinosa and N. Ramírez-Marcial. 2011. Tropical montane cloud forests: current threats and opportunities for their conservation and sustainable management in Mexico. *Journal of Environmental Management* 92: 974–981.

Sánchez-Cordero Dávila studied a Sciences bachelor’s degree in the Faculty of Sciences of the UNAM and the master’s and PhD in the University of Michigan (School of Natural Resources) in the United States. He is a full-time researcher at the Institute of Biology.

His area of expertise includes the modeling of species distribution in aspects of biogeography and conservation of mammals predominantly in Mexico. His research group has made theoretical contributions on the evolution of ecological niches of species, proposing that these ecological niches are conserved throughout evolutionary times, which helps to explain vicarious speciation processes. These theoretical-methodological approaches have also been applied to identify priority areas for biodiversity conservation at different geographic scales and to demonstrate that Mexico’s protected areas are effective instruments for the conservation of biodiversity. In addition, these theoretical approaches have been used to identify geographical areas at risk of emerging infectious diseases of public health importance, such as leishmaniosis and Chagas disease, by modeling the distribution of their reservoirs and potential vectors, respectively.

He has published 83 refereed scientific articles including publications in science, nature, Proceedings of the National Academy of Science, and PLoS ONE, 4 books in national editions, 35 book chapters in national and international editions, and 2 articles in extenso.

Three of his most important and recent publications in conservation biology are:

1. Peterson, A., J. Soberón and V. Sánchez-Cordero. 1999. Conservatism of ecological niches in evolutionary time. *Science* 285: 1265–1267.
2. Peterson, A., V. Sánchez-Cordero, C. Beard, and J. Ramsey. 2002. Ecologic niche modeling and potential reservoirs for Chagas disease, Mexico. *Emerging infectious diseases* 8: 662–667.
3. Herrera M., L. G., J. J. Flores-Martínez and V. Sánchez-Cordero. 2017. Geographical distribution and conservation status of an endemic insular mammal: The Vulnerable fish-eating bat *Myotis vivesi*. *Oryx*. 1–6.

Seventh Edition (2012): Eric Mellink Bijtel, PhD.

He was raised in Mexico's Sonoran Desert and with a background in animal husbandry (B.S., Universidad Autónoma Chapingo, 1979) and arid lands resource sciences and wildlife ecology (PhD, University of Arizona, 1986).

Mellink Bijtel has devoted his carrier to the study of wildlife conservation issues in the Gulf of California, also called Sea of Cortez, a large inlet of the eastern Pacific Ocean along the northwestern coast of Mexico. He has focused on sea and coastal birds, as well as on mammals (especially rodents), but generating information also on reptiles and amphibians.

Mellink Bijtel focuses on understanding the historical processes leading to the current condition of species, communities, or landscapes. Many of his approximately 200 publications have provided information of high value for the management and biological conservation of Mexican fauna, especially of the Gulf of California and Pacific Islands. Mellink Bijtel is also active in the forming of future managers and scientists through both teaching graduate courses and directing M.Sc. thesis and PhD dissertations.

Three of his most important and recent publications in conservation biology are:

1. Mellink E. and M.E. Riojas-López. 2017. The demise of a tropical coastal lagoon as breeding habitat for ground-nesting waterbirds: Unintended, but anticipated consequences of development. *Coastal Management* 45: 253–269.
2. Mellink E., M.E. Riojas-López and M. Cárdenas-García. 2017. Biodiversity conservation in an anthropized landscape: Trees, not patch size drive bird community composition in a low-input agroecosystem. *PLoS ONE* 12(7): e0179438.
3. Mellink, E., M.E. Riojas-López and J. Luévano-Esparza. 2009. Organochlorine content and shell thickness in brown booby (*Sula leucogaster*) eggs in the Gulf of California and the southern Pacific coast of Mexico. *Environmental Pollution* 157: 2184–2188.

Eighth Edition (2013): Enrique J. Jardel Peláez, PhD.

Jardel Peláez is a professor of forest ecology and management at the University of Guadalajara, an institution he joined in 1986 as researcher and field manager at the recently created "Las Joyas" Research Station (LJRS) in the Sierra de Manantlán. This mountain range, located in western Mexico, has functioned for more than 30 years as a site for long-term ecological research and for education and training in biological conservation and natural resource management. It was the initial stage for the establishment of the Sierra de Manantlán Biosphere Reserve (SMBR).

Jardel Peláez participated in the creation and initial management of the SMBR, where he has worked for the last 30 years in projects that integrate scientific research on forest ecology with community-based forest management and wildlands conservation.

His research has contributed in different areas of ecology and has also been very useful in the development of best silvicultural practices, land-use planning, habitat and biodiversity conservation, forest ecosystems management, and fire management.

Applying the experience gained in the SMBR, Jardel Peláez has done consulting and training work in projects about protected area planning, forest management certification, fire ecology, and management in other parts of Mexico, El Salvador, and Cuba. He has also actively participated in national or regional initiatives related to nature conservation, communal forestry, and long-term ecological research.

Three of his most important and recent publications in conservation biology are:

1. Jardel, E.J., A.L. Santiago-Pérez, C. Cortés M. y F. Castillo-Navarro. 2004b. Sucesión y dinámica de rodales. En: R. Cuevas-Guzmán y E.J. Jardel (Editores). *Flora y Vegetación de la Estación Científica Las Joyas*. Universidad de Guadalajara. Guadalajara, Jal. Pp. 179–203.
2. Jardel-Peláez, E.J., R. Cuevas, A.L. Santiago y J.M. Rodríguez. 2014a. Ecología y manejo de los bosques mesófilos de montaña. En: Gual-Díaz, M. y A. Rendón-Correa (Comps.) El bosque mesófilo de montaña de México. Diversidad, ecología y manejo. CONABIO. México D.F. Pp. 141–187.
3. Jardel-Peláez, E.J. 2015. Criterios para la conservación de la biodiversidad en los programas de manejo forestal. *Programa de las Naciones Unidas para el Desarrollo-Comisión Nacional Forestal*. Zapopan, Jalisco, México. 126 Pp.

Ninth Edition (2014): Alfonso Aguirre Muñoz, PhD.

Aguirre Muñoz is an oceanographer and holds an interdisciplinary PhD in social sciences with focus on regional studies. He has a 40 years' professional trajectory that covers environmental conservation, fisheries and aquaculture, academy, and banking and finances for development. For the last 15 years, he has been the executive director of the Ecology and Conservation Group of the Islands (GECI), a science-based nonprofit organization devoted to the restoration and conservation of the Mexican islands (Fig. 10.3), always using and developing the best science methods and working in collaboration with local communities, government agencies, international organizations, and academic institutions.

During this period, GECI became a world leader in the complex field of island restoration and conservation. Before that, he founded and directed "Agromarinos," a successful family business committed to oyster aquaculture and artisanal seaweed fisheries. His varied publications and applied research subjects include teamwork on coastal management and aquaculture, island restoration, and critical reflections in the field of conservation. In addition to "Por Amor al Planeta," Aguirre Muñoz also received the MIDORI Prize for Biodiversity 2016, a Distinguished Citizen Award 2015 honored by the Society of the Ancient California and the municipality of Ensenada, the Pacific Seabird Group Special Achievement Award 2017, and several scholarships.

Three of his most important and recent publications in conservation biology are:

1. Aguirre-Muñoz, A. 2017. Gobernanza ambiental y responsabilidad social para la restauración ecológica en América Latina y el Caribe. In: Zuleta, G.A., A.E. Rovere y F.P.O. Mollard (Eds.), *SIACRE-2015: Aportes y Conclusiones. Tomando decisiones para revertir la degradación ambiental*. Vázquez Mazzini Editores, Buenos Aires, Argentina. Pp. 65–73.

Fig. 10.3 Biodiversity conservation of the Mexican Islands. (Photographs by Alfonso Aguirre)

2. Aguirre-Muñoz, A. et al. 2011. Island restoration in Mexico: ecological outcomes after a decade of eradications of invasive mammals. In: Veitch, C R; Clout, M N and Towns, D R (eds.) 2011. *Island invasives: Eradication and management*. IUCN, (International Union for Conservation of Nature), Gland, Switzerland. Island Invasives International Conference. Auckland, New Zealand. Proceedings.
3. Aguirre-Muñoz, A. et al. 2011. Eradications of invasive species on islands in Mexico: the roles of history and a non-profit organization. In: Veitch, C R; Clout, M N and Towns, D R (eds.) 2011. Island invasives: Eradication and management. IUCN, (International Union for Conservation of Nature), Gland, Switzerland. Island Invasives International Conference. Auckland, New Zealand. Proceedings.

Tenth Edition (2015): Ricardo Rodríguez Estrella, PhD.

Rodríguez Estrella has been an ecologist working with wildlife and their interactions in different ecosystems (e.g., desert areas, temperate forests, islands, and oases) during the last 35 years.

Rodríguez Estrella has contributed to the conservation of biodiversity determining the relevance of critical habitats as oases and desert ecosystems in Northwestern Mexico for the conservation of endemic and predator species. Several species he has studied are now included in the Mexican endangered species act. His work has been useful for the establishment of four national protected areas. He has promoted the belief that oases in the Baja California Peninsula should be included as an officially natural protected area due to their biogeographic history, number of endemics of all biological groups, and their fragility and vulnerability. Furthermore, he has promoted the idea that conservation of oases and their biodiversity be encompassed within the local human populations development. At the present, he has conducted a program of control and eradication of exotic invasive species from these biological systems. In the last years, he has been the head of the scientific group working with the ecology and monitoring of the threatened golden eagle in Mexico.

He has written more than 150 scientific research and educational papers. He has worked in the dissemination of science and environmental education to show to the public the relevance of biodiversity for human development and the need of their conservation.

Three of his most important and recent publications in conservation biology are:

1. Rodríguez-Estrella, R., J.A. Donázar and F. Hiraldo. 1998. Raptors as Indicators of Environmental Change in the Scrub Habitat of Baja California Sur, Mexico. *Conservation Biology*, 12: 921–925.
2. Tella, J. L., J. Figuerola, J.J. Negro, G. Blanco, R. Rodríguez-Estrella, M.G. Forero, M.C. Blázquez, A.J. Green and F. Hiraldo. 2004. Ecological, morphological and phylogenetic correlates of interspecific variation in plasma carotenoid concentration in birds. *Journal of Evolutionary Biology*, 17: 156–164.
3. Holroyd, G. L., R. Rodriguez-Estrella, and S. R. Sheffield. 2001. Conservation of the burrowing owl in western North America: issues, challenges, and recommendations. *Journal of Raptor Research* 35: 399–407.

10.2.2 Support for a Research Project in a Protected Natural Area

This other ward seeks to stimulate scientific and technological research in the country's NPA, from the federal level to the state, municipal, community, and private levels. It distinguished the biological and ecological importance of the area as well as the technical, economic, and scientific viability of the project. The support consists of funding the project with $ 50,000 USD annually for up to 3 years.

The following criteria were taken in consideration to choose the winner of each of the ten editions of the program.

- That the project proposed new techniques for conservation, management, and use of biodiversity.
- That the academic and practical activities proposed in the projects showed biological and ecological importance.

- That the project was represented by a Mexican researcher or by an academic institution that collaborates in an NPA based in Mexico.
- That the projects promoted the training of new researchers and technicians on conservation issues.
- That the project showed the richness of flora and fauna of the NPA, giving priority to conservation projects of endangered species.

10.2.2.1 Winners

First Edition (2006): "Conservation evaluation of Cactaceae species in danger of extinction in the reserve of the biosphere Tehuacán-Cuicatlán." Oswaldo Téllez Valdés

Proposal entitled, "Conservation evaluation of Cactaceae species in danger of extinction in the Biosphere Reserve Tehuacán-Cuicatlán."

During the 3 years that VWM supported this project, the group of researchers and its leader Oswaldo Tellez Valdés PhD could provide information related to endemic species of Mexican Cactaceae as well as the identification of the conservation status of the same and the role that the Reserve (Tehuacán-Cuicatlán) was playing in their protection.

The family Cactaceae is in the major group of angiosperms (flowering plants) and is integrated by 52 genera and 850 species, of which 35% of the genera and 84% of the species are endemic of Mexico. These plants have been used as a source of food, construction material, fuel, and ornamental plants.

The geographic analysis carried out showed the extent of the area where the Cactaceae are located within the Reserve and how this distribution is related to temperature and precipitation patterns. On the other hand, the ecological analysis evaluated parameters such as habitat conditions, reproductive efficiency of the Cactaceae, and estimations of the number of individuals in different areas of the Reserve (Fig. 10.4).

Fourth Edition (2009): "Extending the conservation of the dry forest in the Balsas River Basin: proposal for a protected natural area in the Mixteca Baja Poblana." David Valenzuela

Proposal entitled, "Extending the conservation of the dry forest in the Balsas River Basin: proposal for a protected natural area in the Mixteca Baja Poblana."

This project studied an area of the Mixteca Baja Poblana, southwest of Puebla, where there are important remnants of dry forests, an area that has suffered damages, with high biodiversity rates, but at the same time fragile and one of the least protected ecosystems in the country. Through the results presented, they sustain that this area should be considered an NPA. This region stands out for its biodiversity and its contribution to the recharge of aquifers.

In short, the results showed that 290 plants were found of 77 families and 209 genera: four threatened and one endangered. Endemic species of bats (*Eumops* sp.

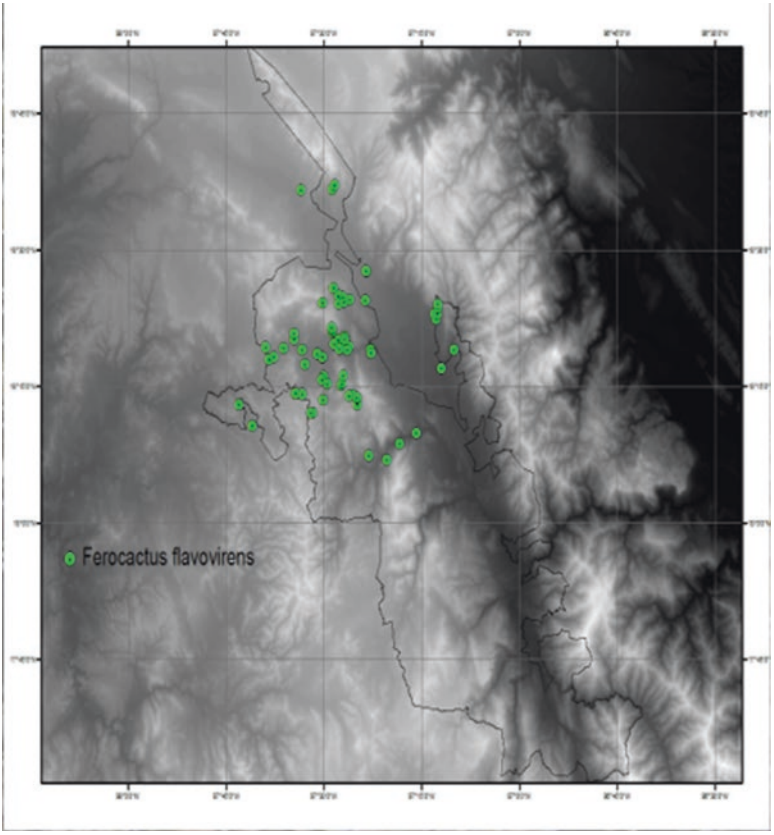

Fig. 10.4 The *green dots* show the distribution in the Tehuacán-Cuicatlán Reserve of *Ferocactus flavovirens*, an endemic species from the Tehuacán-Cuicatlán Reserve. (Image by O. Téllez V)

and *Musonycteris harrisoni*) (Fig. 10.5) were found, the latest in danger of extinction. The identification of 20 species of beetles and 145 morphospecies of 26 families of 5 orders of insects (Coleoptera, Hemiptera, Neuroptera, Hymenoptera, and Orthoptera) was made. Nearly 35 species of ants, 23 genera and 6 families were found, contributing with 24 more species of ants reported in the state of Puebla. Finally, they found five species of two families of mice (Heteromyidae and Muridae).

With all the information gathered by the group of researchers and its leader David Valenzuela Galván, PhD, it was possible to verify the high biological value that dry forest of the Mixteca Baja Poblana represents, so their purpose of making this area an NPA was valid.

Seventh Edition (2012): "La Malinche Science Station: Integrative Research for Conservation and Environmental Education." Margarita Martínez Gómez

Proposal entitled, "La Malinche Science Station: Integrative Research for Conservation and Environmental Education".

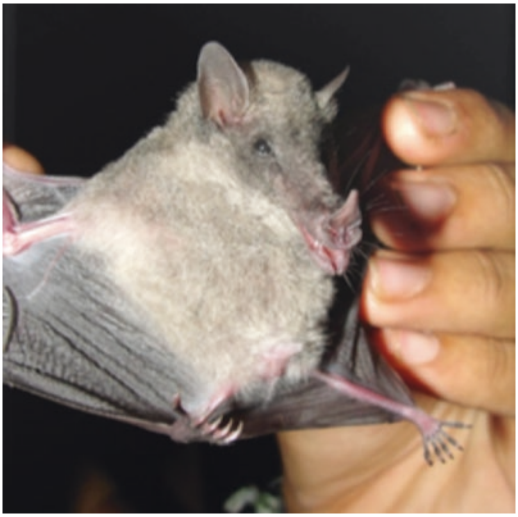

Fig. 10.5 *Musonycteris harrisoni*, endemic species that occurs in the dry forest of the Mixteca Baja Poblana. (Photograph by D. Valenzuela)

The main purpose of the project was to contribute knowledge in the maintenance of the ecosystems of the National Park La Malinche (NPLM) on which only partial information exists on that time. With the support of VWM, they could create La Malinche Scientific Station (LMSS), a facility that favor the conditions for the coordination and development of different investigations. The ecosystems that host the NPLM are characteristic of the high mountains of the Transverse Neovolcanic Axis, site of great biological wealth due to the confluence of two large biogeographic regions and to the geological history of the area.

Margarita Martinez Gómez, PhD, is the leader of a research group that performs an integrative study of the natural resources and biodiversity at NPLM. Some of the results they have found through their investigations showed the identification of 3268 species of bacteria. Of these species *Halomonas nitrophilus*, *Halomonas desiderata*, and *Chthoniobacter flavus* are the most abundant in these ecosystems. The NPLM area shields 19 species of reptiles, which represent 2.19% of the total species in Mexico and 8.7% of the reptiles of the central mountains. Furthermore, there are nine species of amphibians, which correspond to 2.39% of the total Mexican species and 6.8% of the species the central mountains. The monitoring provided a new record of reptiles (*Sceloporus spinosus*) and one of amphibians (*Hyla plicata*). Seven species of bats were recorded, of which *Myotis thysanodes* had not previously been observed in the NPLM.

The implementation of artificial ponds has given back to the fauna of the NPLM a little of the water resource of which it was deprived for several decades. So far, 1 species of amphibian, 30 birds, and 7 mammals are benefiting from the water provided by the ponds to perform their vital activities, such as reproduction and hydration. In addition, the incorporation of nest boxes has significantly favored the reproduction of an increasing number of bird species using secondary cavities.

All the information they have collected through their investigations has been of great support, allowing the detection of critical populations that require special attention. Currently, the LMSS is still being used and new research studies are in process to continue supporting the conservation of NPLM.

10.2.3 Reflections

Biological diversity is a subject of interest to the world. Besides representing the variety of ecosystems, living beings, and their genetic variations, for societies it is established as a source of sustenance, energy, recreation, and food, among other goods and services. Up to now, according to a study published by *PLoS Biology*, about 8.7 million species (give or take 1.3 million) is the new estimated total number of species on Earth (Mora et al. 2011). Their results also suggest that 86% of the species on earth still need to be discovered, an outcome that allows to account for the scientific work that remains to be done.

On the other hand, considering that the current population of the Earth, according to the 2017 revision of the United Nations, is 7.3 billion and is expected to reach 9.8 billion by 2050, the pressure exerted on natural resources will be even greater (UN 2017). As a society, we depend on biodiversity to survive and satisfy our basic needs, and it plays an important role in the economy of the countries, as well as providing environmental services that balance the functioning of the planet. Therefore, it becomes important to promote initiatives that help us to know more about our biodiversity, its importance, and meaning. We need to fill in the gaps as quickly as possible since this will allow establishing lines of research on effective biodiversity conservation.

The award for Scientific Research in Biological Conservation has become the most important recognition in Latin America dedicated to biological conservation, has promoted the career of researchers who obtained such precious recognition, and has become an inspiration for all new researchers from our country.

Some testimonies of the winners of the "Por Amor al Planeta" Award are mentioned below.

> This type of awards sends a very clear signal to new researchers and students about the importance of research in biological conservation in Natural Protected Areas, not only for being valued in the academic environment, but also, and especially, by important actors of the society like VWM. (Eric Mellink Bijtel)

> For us, for our Research Center on Biodiversity and Conservation and for the Autonomous University of the State of Morelos, this recognition has been very positive, since it confirms that our work is doing well and because it highlights our commitment and impact on the conservation of biodiversity and with society in general. An award like the one we have received; no doubt encourages that the scientific research done in the country in biological conservation increases in quality and quantity. (David Valenzuela)

10.3 El Edén Ecological Reserve

El Edén Ecological Reserve A. C. (EEER) is a nongovernmental, nonprofit organization based in Cancun, Quintana Roo, founded by Dr. Arturo Gómez-Pompa and a group of recognized conservationists in the early 1990s. It is the first private ecological reserve dedicated to scientific research on conservation, management, and restoration of biodiversity in Mexico (Gómez-Pompa et al. 2010a). This pioneering initiative has helped discover the possibilities and difficulties of doing and promoting research and conservation projects in private protected spaces.

The EEER is in the Mexican State of Quintana Roo, in the northern portion of the Yucatan Peninsula (Fig. 10.6). It is 30 miles to the NW of the City of Cancun and 15 miles to the north of the town of Leona Vicario, in the region known as "Yalahau" (where the water is born, in Maya).

The project began with the acquisition of approximately 900 hectares (ha). Today EEER has under its protection three additional neighboring properties, with an area of about 3000 ha.

Its original objective was to evaluate the possible contribution of a relatively small NPA to the knowledge and conservation of biodiversity of the Yucatan Peninsula, in contrast with the large size of biosphere reserves. According to United Nations Educational, Scientific and Cultural Organization (2017), biosphere reserves are special places for testing interdisciplinary approaches to understanding and managing changes and interactions between social and ecological systems, including conflict prevention and management of biodiversity. The area of the reserve (Fig. 10.7) was chosen because it has very important characteristics. The most notable was the scarcity of biological, ecological, archeological, anthropological, and environmental

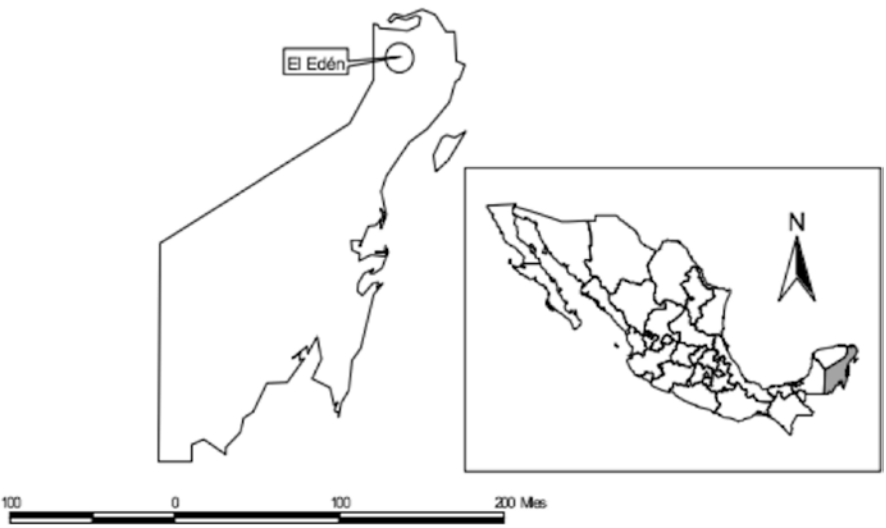

Fig. 10.6 The Mexican State of Quintana Roo is shown in *black* in southern Mexico (inset), and the circle shows the location of El Edén Ecological Reserve. The bar scale applies to Quintana Roo. (Image from Gómez-Pompa et al. 2003)

Fig. 10.7 Photograph that shows the area of the EEER. (Photograph by Emmanuel Solis)

studies in an unpopulated region. It was the last great unexplored area of natural savannah in the northeastern portion of the Yucatan Peninsula. The area was inhabited and uninhabited several epochs over periods of time. Little was known about the presence and activities of ancient Maya in the area.

A variety of habitats are present, tropical savannahs, secondary forests, seasonally inundated forests, wetlands, and several small lagoons. The known flora is made up of 404 species (Schultz 2005) and represents approximately 18% of all species of known plants (2300) in the Yucatan Peninsula. The known mammals are made up of 9 orders and 23 families. In the reserve lives one of the members of the Felidae family with the highest risk of extinction, the jaguar (*Panthera onca* – Fig. 10.8), along with four other felids, which are also threatened. A group of conservationists in the EEER headed by Marco Lazcano are currently working on the conservation of the jaguar, assuring their well-being, reproduction, and a protected permanent habitat. Several other biological inventories have been initiated and published: birds, bats, rodents, fishes, amphibians, butterflies, fungi, slime molds, diatoms, and others.

The climate at the EEER region is characterized by an extended winter/spring drought, with the wet period beginning in June or July and a dry season from November to June. The Yalahau bioregion, where the reserve is located, is subject to hurricanes and is periodically inundated, creating macrohabitats and microhabitats for numerous species of aquatic and semiaquatic organisms. The inundated savannah (Fig. 10.9) is an interesting vegetation type for studying wetlands (Novelo and Tavera 2003). Fires are also relatively common, and their intensity and frequency are apparently related to the quantity of fallen timber left after hurricanes and to fires started during each dry season usually by farmers for land-clearing purposes.

Fig. 10.8 *Panthera onca* in EEER. (Photograph by Marco Lazcano)

Fig. 10.9 The EEER inundated. (Photograph by Cristina MacSwiney)

The reserve's scientific research is widely recognized nationally and internationally and its prestige as a leading conservation organization is appreciated by the national conservation community. The scientific information generated on the biological, ecological, and chemical diversity of the EEER is unique in the country and a model to be followed by other NPA. In its short existence, it has become one of the best known NPAs from the biological and archeological perspective of Mexico. Its ecological restoration works are also widely known and appreciated.

EEER is perhaps one of the very few protected areas where long-term experimental biology and field ecology research in the management and conservation of biodiversity is encouraged. A significant benefit to the use of experimental biology in conservation and environmental management is its ability to isolate the effects of stressors or cause by performing experiments under controlled conditions, which allows scientists to separate the effects of a variable from other possible effects (Seebacher and Franklin 2012). Experimental ecology and conservation science can strive to develop solutions that are relevant to the problem and realistic to the end users. Research funding must be directed toward practical solutions that can be acceptable to stakeholders (Cooke et al. 2017; FWS 2015).

Research done at the EEER has proven that highly disturbed sites have great scientific value. The discovery of managed wetlands (Fig. 10.10) by the ancient Maya has been considered one of the most important scientific findings of the last decades. "Understanding the past and present dynamics of wetlands . . . holds a key to understanding the evolution of Maya civilization" (Jacob 1995).

The *Lowland Maya Area: Three Millennia at the Human-Wildland Interface*, book published in 2003 by the editors A. Gómez-Pompa, M. F. Allen, S. Fedick, and J. Jiménez-Osornio, is one of the most important publications of EEER done in collaboration with the University of California, Riverside (UCR).

Wetlands are one of the most biologically active ecosystems; therefore, they are ecosystems with very high net primary productivity (Novelo and Tavera 2003). Understanding the management of wetland resources over time in a distinctive environment provides a unique opportunity. The El Edén wetland consists of a large, shallow depression measuring approximately 5.5 km north-south by 0.8 km east-west (Fedick and Morrison 2004).

The presence of wetlands in the EEER makes the zone attractive for studying algae (diatom flora). Eberto Novelo, Rosaluz Tavera, and Claudia Ibarra headed a big study published in 2007, in which they focused on karstic wetlands to identify the diatom flora present at El Edén. Out of the 156 taxa identified in the Reserve, nine were recognized as new species and three new combinations were proposed (Novelo et al. 2007 p. 4).

"Los Hongos de El Edén": An introduction to the tropical mycobiota of Mexico is another significant publication of the EEER. This book written by Gastón Guzmán in 2003 provides a lot of valuable information of the tropical fungi of Mexico. His investigation showed that EEER hosts one third of the myxomycetes diversity known for the entire country (Guzmán 2003).

One important successful project facilitated and promoted by the EEER to stimulate scientific education was created by Dr. Dan Bisaccio. He used the protocols developed by the Smithsonian Institution, Program of Man and the Biosphere

Fig. 10.10 Cenote at the EEER area. (Photograph by Emmanuel Solis)

(SIMAB), to educate more than 700 high school students from Mexico, the United States, Asia, and Europe in learning methods for biodiversity research and monitoring and allowed students to learn about ecology and biodiversity by doing research projects in the field (Fig. 10.11).

Throughout 20 years, the EEER has been an important promotor of regional conservation: actively participating in the prevention, detection, and combat of wild fires; inspection and surveillance to avoid land invasion; the fight against hunting; and the extraction of illegal forest resources.

EEER has proven its resistance to one of the costliest and destructive hurricanes (Wilma) in the history of the region. The Reserve experienced 36 h of a category 4 hurricane and its passage through the area left floods and damaged 70% of its rustic infrastructure. Studies of its ecological impact and recovery from Wilma have been made possible by the information gathered before and after the hurricane by a team of scientists working at EEER.

The most substantial proof of success of the EEER as the first private ecological reserve dedicated to scientific research on conservation in Mexico are the studies that have been published in different lines of investigations, as well as all the students that have been able to take advantage of its facilities and resources to learn and create valuable knowledge. “La Sabana Research Station” was built to accommodate scientists and occasional visitors. As a result, there have been 30 bachelor’s, master’s, and doctoral theses, 49 scientific publications, 13 science communication articles, more than 30 scientific reports, and 4 books with topics of archeology, agroecology, biodiversity, chemical diversity, and ecology based on the Reserve. Several new species have been discovered.

Fig. 10.11 Students of Dr. Dan Bisaccio in a field expedition at EEER. (Photograph by Dan Bisaccio)

- Endophytic fungus: *Edenia gomezpompae* (Macías-Rubalcava et al. 2008)
- Diatom: *Aulacoseira periphytica* sp., *Caloneis subanicola* sp., *Capartogramma paradisiaca* sp., *Cymbopleura cachii* sp., *Encyonema densistriata* sp., *Fragilaria dzonoticola* sp., *Nitzschia yalahau*, *Pinnularia mayarum*, *Stauroneis amphibia* sp. (Novelo et al. 2007)

Each project and publications attracts new scientists and students, creating collaborative projects in different subjects. Below we present a table (Table 10.1) with some of the selected publications of the EEER, classified by research area. A complete list can be consulted in the web page of the Reserve.[1]

Specific examples of important studies on the priority research areas or lines of investigation at the EEER are mentioned below. It is important to remark that these lines were initially chosen by the Advisory Board of the Reserve followed by a group of scientists that were invited to participate in research projects of the EEER. This initial group of scientists began the first studies and acquired an initial funding by small grants from UCR.

[1] www.reservaeleden.mx

Table 10.1 List of selected publications that have been done in El Edén in the priority areas of research of the EEER

Research area	Publications
New taxa	Macías-Rubalcava ML, Hernández-Bautista BE et al. (2008). Naphthoquinone spiroketal with allelochemical activity from the newly discovered endophytic fungus *Edenia gomezpompae*. Phytochemistry 69(5): 1185–1196
Restoration ecology	Allen, M. F, Gómez-Pompa, A et al. (2005). Effects of mycorrhizae and nontarget organisms on restoration of a seasonal tropical forest in Quintana Roo, Mexico: factors limiting tree establishment. Restoration ecology, 13: 325–333
Wetland ecology	Becerra-Absalón I, Tavera R (2003). Cambios de la comunidad algal (Perifiton) relacionados con el ciclo hidrológico en un tintal anegable en Quintana Roo. Estudios Mexicanos 19(2): 263–275
	Calderón-Medina ET (2006). La comunidad fitoplanctónica de un humedal tropical en la Reserva Ecológica el Edén, Quintana Roo, Mexico. Biología (UNAM Facultad de Ciencias). México D.F., Universidad Nacional Autónoma de México. Tesis de Licenciatura: 95 p
	Ibarra C, Novelo E et al. (2009). Diversity and structure of periphyton and metaphyton diatom communities in a tropical wetland in Mexico. Revista Mexicana de Biodiversidad, 80(3), 763–769
	Novelo E, Tavera R (1999). Algas y humedales de Quintana Roo. Ciencias. Facultad de Ciencias, UNAM. 55–56:44–45
	Novelo E, Tavera R (2003). The role of periphyton in the regulation and supply of the nutrients in a wetland at El Edén, Quintana Roo. In: Gómez-Pompa A, Allen MF et al. (eds) The lowland Maya area: three millenia at the human-wildland interface. Food Product Press, U.S.A, pp. 217–239
	Vargas Ramos R, Novelo E (2003). Nitrogen fixation by cyanoprokaryotes in the Eden Ecological Reserve in Quintana Roo, Mexico. Estudios Mexicanos 19(2): 277–285
Chemical ecology	Anaya AL, Mata R et al. (2003). Allelochemical potential of *Callicarpa acuminata*. Journal of Chemical Ecology 29(12): 2761–2776
	Flores-Carmona MDC, Cruz-Ortega R et al. (2008) Allelopathic potential of some tropical trees of Ecological Reserve El Edén, Quintana Roo, Mexico. Allelopathy Journal 21(1): 57–72
	Macías-Rubalcaba ML, Hernández-Bautista BE et al. (2010). Allelochemical effects of volatile compounds and organic extracts from *Muscodor yucatanensis*, a tropical endophytic fungus from *Bursera simaruba*. Journal of Chemical Ecology 36: 1122–1131
	Pech GG, Brito WF et al. (2002). Constituents of *Acacia cedilloi* and *Acacia gaumeri*. Revised structure and complete NMR assignments of Resinone. Z. Naturforsch. 57c: 773–776
	Romero-Romero T, Anaya AL et al. (2002). Screening for effects of phytochemical variability on cytoplasmic protein synthesis pattern of crop plant. Journal of Chemical Ecology 28(3): 617–629
	Sauceda Garcia A (2006). Busqueda de compuestos bioactivos en hongos antagonicos endofitos de plantas con potencial aleloquimico de la Reserva Ecologica El Edén, Quintana Roo. Ciencias Biológicas (UNAM Instituto de Ecología). Mexico D.F, Universidad Nacional Autónoma de México. Tesis de Maestría: 75 p
	Vargas Ramos, R. (2009). On the fate of old stored carbon after large- infrequent disturbances in plants. Plant Signaling and Behavior 4(7): 617–619

(continued)

Table 10.1 (continued)

Research area	Publications
Biodiversity	Andrade-Torres A. (1997). Riqueza abundancia y diversidad de myxomicetes sobre hojarasca, troncos caídos y cortezas de árboles tropicales vivos. Facultad de Biología, Universidad Veracruzana. Tesis de Licenciatura
	Cózatl-Manzano R, Naranjo-Garcia E (2007). First records of freshwater molluscs from the Ecological Reserve El Edén, Quintana Roo, Mexico. Revista Mexicana de Biodiversidad 78(2): 303–310
	Gómez Espinosa MC (1999). Taxonomía y biogeografía de los moluscos terrestres de la Reserva Ecológica El Edén. Quintana Roo. Biología (UNAM Facultad de Ciencias). México D.F, Universidad Nacional Autónoma de México. Tesis de Licenciatura: 69 p
	Heaton HJ, Gómez-Pompa A et al. (1999). Extreme ecological and phenotypic differences in the tropical tree chicozapote (*Manilkara zapota* (L.) P. Royen) are not matched by genetic divergence: a random amplified polymorphic DNA (RAPD) analysis. Molecular Ecology 8(4): 627–632
	Hernández RAM (1999). Estudio de la diversidad de la vegetación secundaria en la Reserva Ecológica El Edén, Quintana Roo. Escuela de Biología. Benemérita Universidad Autónoma de Puebla. México. Tesis de Licenciatura: 79 p
	Ibarra C, Tavera R et al. (2009) Diversity and structure of periphyton and metaphyton diatom communities in a tropical wetland in Mexico. Revista Mexicana de Biodiversidad 80: 763–769
	León-Cortés JL, Jones RW et al. (2003). A preliminary assessment of the butterfly fauna of El Edén Ecological Reserve: species richness and habitat preferences. In: Gómez-Pompa A, Allen M.F, et al. (ed) The lowland Maya area: three millenia at the human-wildland interface. Food Product Press, U.S.A, pp. 261–276
	MacSwiney GMC. (2000). Estructura de la comunidad de quirópteros de la Reserva Ecológica El Edén, Quintana Roo, México. Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Yucatán. Tesis de Licenciatura: 58 p
	Schultz GP (2005). Vascular flora of the El Edén Ecological Reserve, Quintana Roo, Mexico. Journal of the Torrey Botanical Society 132(2): 311–322
Animal ecology	González-Marín RM, Gallina S et al. (2008). Densidad y distribución de ungulados silvestres en la Reserva Ecológica El Edén, Quintana Roo, México. Acta Zoológica Mexicana (n.s.) 24(1): 73–93
	MacSwiney GMC, Bolívar-Cimé B et al. (2009). Insectivorous bat activity at cenotes in the Yucatan Peninsula, Mexico. Acta Chiropterologica 11(1): 139–147
	MacSwiney GMC (2007). Ecology and conservation of bat assemblages associated with water-filled sinkholes (cenotes) in the Yucatan Peninsula, Mexico. Animal Ecology. University of Aberdeen, UK. Tesis de Doctorado: 152p
	MacSwiney GMC, Clarke FM et al. (2008). What you see is not what you get: the role of ultrasonic detectors at maximising inventory completeness in Neotropical bat assemblages. *Journal of Applied Ecology* 45(5): 1364–1371
	MacSwiney GMC, Vilchis P et al. (2007). The importance of cenotes in conserving bat assemblages in the Yucatan, Mexico. *Biological Conservation* 136(4): 499–509
	Torres-Romero EJ (2009). Densidad, abundancia, uso de habitat y patrones de actividad del ocelote (*Leopardus pardalis*) en la zona noreste del estado de Quintana Roo: estudio usando cámaras trampas. El Colegio de la Frontera Sur. Tesis de Maestría
	Panti-May JA, MacSwiney GMC et al. (2015). Reproduction and postnatal development in the Yucatan vesper mouse. Mammalia 79(2): 169–176

Archeology	Fedick SL (1998). Ancient use of wetlands in Northern Quintana Roo, Mexico. In: K. Bernick (ed) Hidden dimensions: the cultural significance of wetland archaeology. University of British Columbia Press, Vancouver, BC, pp. 107–129
	Fedick SL, Morrison BA (2004). Ancient use and manipulation of landscape in the Yalahau region of the northern Maya lowlands. Agriculture and Human Values 21: 207–219
	Fedick SL, Morrison BA et al. (2000). Wetland manipulation in the Yalahau Region of the Northern Maya Lowlands. Journal of Field Archaeology. 27(2): 131–152
	Gómez-Pompa A, Allen MF, Fedick SL, Jiménez-Osornio JJ (eds) (2003). The lowland Maya area: three millenia at the human-wildland interface. Food Product Press, U.S.A
	Mathews JP (1998). The ties that bind: the Ancient Maya interaction spheres of the Late Preclassic and Early Classic Periods in the Northern Yucatán Peninsula. Anthropology, University of California, Riverside. University Microfilms, Ann Arbor
	Morrison B (2000). Ancient Maya settlement of the Yalahau region: an example from the El Edén wetland. Anthropology. University of California, Riverside. Tesis de Doctorado: 210p
Agroecology and plant ecophysiology	Flores-Delgadillo L, Fedick SL et al. (2011). A sustainable system of a traditional precision agriculture in a Maya homegarden: soil quality aspects. Soil and Tillage Research 113(2): 112–120
	Goode LK, Allen MF (2009). Seed germination conditions and implications for establishment of an epiphyte, *Aechmea bracteata* (Bromeliaceae). Plant Ecology 204: 179–188 Goode LK, Allen MF (2008). The impacts of hurricane Wilma on the epiphytes of El Edén Ecological Reserve, Quintana Roo, Mexico. Journal of the Torrey Botanical Society 135(3): 377–387
	Hasselquist NJ, Santiago LS et al. (2010). Belowground nitrogen dynamics in relation to hurricane damage along a tropical dry forest chronosequence. Biogeochemistry 98: 89–100
	Hasselquist NJ, Allen MF et al. (2010). Water relations of evergreen and drought-deciduous trees along a seasonally dry tropical forest chronosequence. Oecologia 164: 881–890
	Ramírez-Trejo MR, Pérez-García B et al. (2010). Effect of fire on the germination of spores of *Pteridium caudatum*, an invasive fern. Journal of Tropical Ecology 26: 457–465
	Vargas Ramos R, Allen MF et al. (2008). Biomass and carbon accumulation in a fire chronosequence of a seasonally dry tropical forest. Global Change Biology 14(1): 109–124
	Vargas Ramos R, Trumbore SE et al. (2009). Effects of vegetation thinning on above- and belowground carbon in a seasonally dry tropical Forest in Mexico. Biotropica 41(3): 302–311
	Vargas Ramos R, Allen E et al. (2009). Evidence of old carbon used to grow new fine roots in a tropical forest. New Phytologist 182: 710–718
Education	Bisaccio DJ (2003). HabitatNet: Conducting biodiversity research with secondary-school science class. In: Gómez-Pompa A, Allen MF et al. (eds), The lowland Maya area: three millenia at the human-wildland interface. Food Product Press, U.S.A. pp. 611–619

- Biodiversity
  This priority area of research began its activities since the Reserve's creation. The long-term objective was to have an inventory of all the species of the EEER. As an example of this, we can mention the work of Gillian P. Schultz who produced the first large-scale qualification and quantification of the vegetation of the Reserve and initiated the inventory of the flora. Another example is the inventory of freshwater mollusks of El Edén. Eleven species of freshwater mollusks were found (Cózatl-Manzano and Naranjo-Garcia 2007).
- Wetland Ecology
  Studies of wetland ecology were created in the EEER by a group of scientists from UNAM, headed by Norberto Novelo PhD, and his students. They initiated the inventories of algae. They began their research by investigating the structure and diversity of diatoms in communities of metaphyton and periphyton from the wetlands of El Edén (Ibarra et al. 2009).
- Archeology
  Another priority line of investigation is the historical ecology of the region. This line of research was headed by archeologist Scott L. Fedick of UCR. The studies provide information of how the Maya could transform what might seem to be a wetland wasteland into a managed productive landscape (Fig. 10.12). Their investigations suggest the hypothesis based on archeological evidence that the ancient Maya manipulated and managed the wetland mud rich in nutrients from the algae (periphyton) to be used probably as a fertilizer (Fedick and Morrison 2004).
- Chemical Ecology
  This priority line of investigation was headed by Dr. Ana Luisa Anaya from UNAM. This research focuses on the allelochemical potential of the flora of the EEER (Anaya et al. 2003). One example was the chemical investigation of the mycelium of *Edenia gomezpompae*, a newly discovered endophytic fungus isolated from the leaves of *Callicarpa acuminata* collected from El Edén (Macías-Rubalcava et al. 2008).
- Agroecology and Plant Ecophysiology
  As an example of this priority, it is worth mentioning an investigation that was developed at EEER by a group of scientists from UCR headed by Michael Allen, Edith Allen, and their students. During this investigation, the first attempts were made to quantify biomass above and below ground and carbon stocks to calculate the seasonal recovery of dry forests after the fire (Vargas Ramas et al. 2008).
- Restoration Ecology
  This priority research area was headed by a team of scientists from UCR: Michael Allen and Edith Allen. They analyzed the effects of mycorrhizal fungal community composition on the restoration of tropical dry seasonal forest trees (Allen et al. 2005).
- Animal Ecology
  The EEER has this priority as an important line of research. The newest example is the study on rodent communities with arboreal habits that has been carried out at the Reserve. The Yucatán vesper mouse *Otonyctomys hatti* is one of the endemic species of the Yucatan Peninsula that exhibits low population density with strict arboreal habits, depending on the conservation of the mature tropical forests of the region (Zaragoza-Quintana et al. in prep.).

Fig. 10.12 Constructed features within the seasonally inundated wetland consist of alignments of limestone boulders and slabs apparently intended to function as dikes and check dams to control water and sediments. (Photograph by Scott L. Fedick)

10.3.1 Reflections

Protected areas have been a main instrument of ecosystem conservation and have contributed to stopping ecosystem degradation and to maintaining essential ecological processes (Pujadas and Castillo 2007). The EEER is a different type of protected area that promotes research in private lands (Gómez-Pompa 1998).

For their outstanding actions, the EEER in 2005 received the Nature Conservation Award by the Ministry of Environment and Natural Resources of Mexico (SEMARNAT) and the National Commission of Natural Protected Areas (CONANP).

The long-term existence of this private conservation experiment will be strongly linked to the support and protection it receives from federal, state, and municipal authorities. Its survival depends on the support given by conservation organizations to stimulate the creation of many more private reserves dedicated to research in different fields. Its success also depends of available funding from donations of friends and philanthropists interested in the conservation of the biotic heritage of Mexico.

The EEER has received important support from the following institutions: UCR, UNAM, Yucatan Autonomous University (UADY), University of Veracruz (UV), and Souhegan High School.

10.4 Final Remarks

Most lands in protected areas in Mexico are not state owned. There is a mosaic of tenancy that includes private lands owned by individuals or nongovernmental organizations (NGOs) and communal properties managed by indigenous or peasants' communities (Pujadas and Castillo 2007). Most lands in the National System of Protected Areas belong to "ejidos" or indigenous groups living within or adjacent to protected areas.

EEER model could be used to bring scientific research and to give the necessary support to this type of dual conservation in collaboration with research and educational institutions, government, and other private reserves.

Biological and ecological conservation should not be only by decree; the participation of smallholders, private groups, and individuals who can help in this national effort should be sought and encouraged. The need to involve people in the conservation process implies more than solely informing people about the "rightful" implementation of nature conservation. Rather, it entails abandoning the top-down and hegemonic attitude where nature is perceived as a scientific question only, not directly intelligible to humans, and which needs to be conveyed through science (Skandrani 2016).

All kinds of incentives should be given for the creation of private protected areas of all kinds, especially those proposed by indigenous groups. We recommended to carry out an in-depth study on the endemic biota of Mexico. These resources are unique to the country and therefore we have a great responsibility for their care. We need to create conscience to the public on the importance of research and the need for conservation and educational projects in local rural communities with participation of local schools and children. An example of this approach is the book "Atlas de la Flora de Veracruz" (Castro-Cortés et al. 2010) and the project of "Plants of my Community"[2] produced by the UV with collaboration from EEER.

The set of NPAs of Mexico does not protect the biological and ecological diversity of the country. It is necessary to encourage the creation of new NPAs by providing evidence through experimental biology and conservation science that supports the need of protecting those critical areas. Although an expanding human footprint and rapidly changing environment have led to increasingly complex and difficult conservation questions, experimental biology can produce the evidence needed to address many of the key questions so that solutions can be found across a range of relevant scales (Cooke et al. 2014). The best-managed formally protected areas are those under the care of research centers and/or higher education. Such an arrangement should be promoted with all priority areas.

[2] www.reservaeleden.org/plantasloc/

Knowledge of the flora, fauna, and microorganisms of Mexico is still very scarce. It is essential to promote the study of this national biotic wealth. It is recommended to initiate an urgent program to carry out a comprehensive assessment of the biological diversity we have in the country's protected areas. We cannot make a good planning of the additional needs of biological conservation if we do not know what is already protected. The two approaches we described in this chapter showed us the importance of promoting scientific research in conservation biology as well as providing us valuable information of the biodiversity and ecology of Mexico.

We should stimulate the creation of projects such as the Volkswagen Award in order to promote the formation of new Mexican scientists in conservation biology and recognize the current contributions made by scientists. As we mentioned before, establishment of private reserves initiatives should be reinforced. The government and research institutions must support and offer incentives to the creation of private reserves such as EEER. That way, we could generate scientific research to explore the best approaches for the protection of rare and endangered species and ecosystems.

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Chapter 11
Forgotten Social Issues for Achieving Long-Term Conservation in Protected Areas

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Abstract Protected areas (PAs) are probably the most important conservation instrument in Mexico. Historically, their planning and implementation have focused on ecological data ignoring values, attitudes, behaviors, and institutions of the people living in the PA, thus inhibiting its long-term effectiveness. Here, we review three social disciplines that might enhance the understanding of the social sphere around PAs: conservation psychology (CP), social-ecological system framework (SESF), and conservation marketing (CM). CP is crucial to understand human behavior toward nature or conservation. We present different tools for evaluating values, attitudes, and behaviors that are relevant for understanding conservation outcomes. SESF allows to systematically map and diagnose the pattern of interactions of relevant variables in search of factors that can be promoted or restricted to enable the involvement of local people in the planning and implementation of conservation programs and instruments. Finally, CM allows us to modulate and design conservation programs with specific end-state behaviors and target audiences to improve the success of the conservation actions. We proposed that using these disciplines in the design, implementation, and evaluation of the conservation programs, we will enable effective long-term conservation inside Mexican PAs.

Keywords Local governance · Co-management · Conservation marketing · Conservation psychology · Social-ecological system framework

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11.1 Introduction

Protected areas (PAs) are one of the most common tools for the conservation of biodiversity worldwide. Historically, PAs were created based on biological or ecological criteria (Halfter 2005), and human settlements within or adjacent to them were viewed as threats to their natural preservation (Redford and Sanderson 2000; Sarkar 1999). In this sense, the paradigm of early PAs was preservation of the environment, even if that meant removing the local communities from the area (Adams and Hutton 2007; Agrawal and Redford 2006). Following this preservation paradigm, policymakers aimed to create PAs in pristine habitats (Sarkar 1999), ignoring the social and economic impacts of their creation and management (Adams and Hutton 2007; Halfter 2005).

11.1.1 Protected Areas and the Paradigm Shift from Preservation to Conservation

The preservation paradigm has been questioned for its lack of long-term effectiveness. Even uninhabited, PAs can suffer harmful human influences such as climate change or the synergistic effect of fragmentation (Barnosky et al. 2012; Root and Schneider 2006; Vitousek et al. 1999). Moreover, the preservation approach is characterized by poor communication strategies and low participation with the local communities (Adams et al. 2004; Adams and Hutton 2007; Agrawal and Redford 2006; Wilshusen et al. 2002). Without communication or participation from local communities, PAs are still threatened by the effects from the surrounding areas. As a consequence, understanding the norms and factors that affect the management of the territory surrounding PAs is the best way to accomplish long-term conservation goals (Palomo et al. 2014). Analyzing communities that live inside or around PAs and studying how they manage the use of natural resources are vital aspects of a successful PA implementation.

Eventually, a new concept of PA management emerged, called the conservation paradigm. PAs created following the conservation paradigm have two goals: to conserve biodiversity and to improve the quality of life of their inhabitants through sustainable use of natural resources (Adams and Hutton 2007; Brockington and Wilkie 2015). This sustainable development approach constitutes a complex system. Therefore, conservation efforts performed inside the PAs should address social, cultural, and political goals to alleviate poverty and improve economic development and political participation (Halfter 2005; Minteer and Miller 2011; Salafsky 2011).

11.1.2 Protected Areas in Mexico

Mexico has a long history of protecting biodiversity. Currently, there are seven legal methods to protect biodiversity: environmental impact assessment (MIA), wildlife management unit (UMA), national forestry program (PRONAFOR, PSA), fishing refuge area (ARP), voluntary scheme for forest certification (SCEFORMEX), program of ecological general panning of the territory (POEGT), and protected areas (PAs). Of the seven, PAs have the longest tradition of use in Mexico and are probably the most important, as the other six methods can be implemented within PAs.

Mexican federal PAs are still designated by decree mainly following the current conservation paradigm, without an understanding of the cultural and ecological context. Mexico has more than 180 PAs, and their management depends on the National Protected Areas Commission (SEMARNAT and CONANP 2017). A specific management plan (PM) and an annual operative program are the principle guidelines for the management of the Mexican PAs. The National Commission of Natural Protected Areas (CONANP) directs the human and economic resources to monitor, patrol, manage, and promote sustainable development in each PA (Pisanty et al. 2016).

11.1.3 Conservation Programs Inside PAs in Mexico

Ensuring conservation inside PAs is a challenge. The Ministry of Environment and Natural Resources (SEMARNAT) and CONANP have developed several conservation programs that aid PA managers in achieving their conservation goals. All these conservation programs emerged during the last 30 years. Following the conservation paradigm, most of the conservation programs focus on the social aspects of conservation, and only two of them, the fishing refuge area and the environmental impact assessment, focus mainly on the environment. All of these programs are targeted to the local communities living in areas with high conservation value, and most of them focus on economic incentives (i.e., subsides) to engage the targeted audience (Table 11.1).

11.1.4 Long-Term Effectiveness of Mexican PAs and Its Conservation Programs

To ensure long-term conservation, it is compulsory to assess the effectiveness of PAs and the conservation programs; nonetheless, this is rarely done. There are plenty of methods to evaluate the effectiveness of PAs, such as the Effectiveness Index for the Management of PAs (Ortiz and Ortega-Rubio 2015) and WWF-IUCN-GTZ Effectiveness Measurement for PAs (Cifuentes et al. 2000). However, the most

Table 11.1 Conservation instruments or programs in Mexico

Conservation method or program	Aim	Year of creation	Beneficiaries	Type of benefits	Reference
Protected areas	To conserve areas of the national territory where the original environments have not been significantly altered by the activity of humans or that need to be preserved and restored	1917	Environment and local and/or regional community	Environmental and economic benefits	CONANP (2016b)
Environmental impact manifestation (MIA)	To determine the significant and potential environmental impacts related to construction work or activity as well as analyze the manner to avoid or mitigate this effect if it is detrimental to the environment or human health	1988	Environment m and local and/or regional community	Environmental benefits	SEMARNAT (2013)
Wildlife management unit (UMA)	To strength the integral management of habitat, populations, and native species with particular emphasis on threatened and priority species	2000	Citizens and social groups	Economic benefits gained by landowners (e.g., small entrepreneurs) due to the sustainable use of the wildlife	SEMARNAT (2016)
National forestry program (PRONAFOR)	To support the owners and holders of forests, jungles, mangroves, wetlands, and arid, to care, improve, and sustainably exploit forest resources present in these ecosystems	2003	Organizations and private or social landowners	Economic subsidies as payments for ecosystem services focusing on:	CONAFOR (2015)
				1. Hydric ecosystem services	
				2. Biodiversity conservation	
Program of Recovery and Repopulation of Species in Danger of Extinction (PROCER)	To contribute to the maintenance of species at risk and their habitat, promoting collaboration and participation of higher education institutions, research, and civil society organizations, *ejidos*, and communities, for sustainable development in the municipalities of the priority regions where these species are distributed	2007	Higher education and research institutions, civil society organizations, and users of the resources	Economic subsidies for:	CONANP (2017a)
				1. Conservation of species at risk	
				2. In situ conservation of Criollo maize	
				3. Social compensation for the temporary suspension of fishing to contribute to the preservation of the vaquita porpoise	

Fishing refuge area (ARP)	To create specific zones where the fishing effort is controlled entirely or partially in defined geographical areas in any aquatic zone (marine or continental), allowing the conservation of the ecosystem and the natural restoration of its functions and structure	2007	Ecosystem and local and/or regional community	Environmental benefits	CONAPESCA (2012)
				No direct economic benefit	
				Contribute to the development of sustainable fishery	
Voluntary scheme for forest certification (SCEFORMEX)	To create a voluntary process by which an independent third party ensures, through a certificate, that the management of a forest is sustainable and carried out in compliance with the preestablished criteria	2008	Private or social (*ejido* and communal) landowners	Economic benefit due to value-added products	SEMARNAT, CONAFOR (2015)
Temporary Employment Program (PET)	To contribute to the socioeconomic welfare of the inhabitants of PAs by paying wages equivalent to 99% of the current daily minimum wage to participate in a given conservation action	2009	Local community since the age of 16	Economic subsidy for:	CONANP (2017b)
				1. Conservation, restoration, and sustainable development (e.g., soil conservation, solid waste recycling, sustainable use of water and wildlife)	
				2. Actions to mitigate the impact of climate change (e.g., fire prevention)	
				3. Intermittent PET	
Conservation Program for Sustainable Development (PROCODES)	To promote the conservation of ecosystems and their biodiversity through its sustainable use, with equal opportunities for women and men and with emphasis on the indigenous population	2009	Local community with preferences of women and indigenous groups	Economic subsidy for:	CONANP (2015)
				1. Conservation projects or infrastructure	
				2. Training courses	
				3. Technical studies	
				4. Environmental contingency brigades	

(continued)

Table 11.1 (continued)

Conservation method or program	Aim	Year of creation	Beneficiaries	Type of benefits	Reference
Management Program of Natural Protected Areas (PROMANP)	Promote the conservation of ecosystems and their biodiversity through the generation of information on biodiversity, the direct and effective participation of the local population, and the analysis of management strategies	2011	Academic and research institutions, centers of research, civil, social organizations, and citizens	Economic subsidy for:	CONANP (2016a)
				1. Community surveillance	
				2. Strengthening of ANP through technical studies	
				3. Biological monitoring	
Program of Ecological General Planning of the Territory (POEGT)	Ecological regionalization (which identifies the priority attention areas and the areas of sectoral aptitude) and the ecological guidelines and strategies for the preservation, protection, restoration, and sustainable use of natural resources	2012	Ecosystems, federal government, country	Environmental and economic benefits due sustainable development	SEMARNAT (2012)

common method implemented in Mexican PAs relies on identifying patterns of land-use change (Figueroa et al. 2011; Figueroa and Sánchez-Cordero 2008). However, this method only focuses on the ecological success and should be paired with an assessment of socioeconomic changes. In 2001, CONANP founded the National System of Information, Monitoring and Evaluation for Conservation (SIMEC), with the aim to analyze geographic, biologic, social, and economic indexes to evaluate the effect of PAs; however, their information is still limited due to budgetary constraints (Pisanty et al. 2016). In general, studies have found that Mexican PAs tend to be effective in preventing land-use change but ineffective in improving the livelihood of their inhabitants (Figueroa et al. 2009; Jiménez-Sierra et al. 2017).

The ineffectiveness to reach the social goals in the PAs is not related to a lack of understanding of nature but rather to a lack of understanding of humans. PA conservation research should be less about answering ecological questions (such as what are the threats to diversity or how does specific threat affect the species or ecosystem?), and more about solving social problems (as how do humans value biodiversity; what are the current values, attitudes, beliefs, and actions of a community; and how can we change the current unsuitable practices to conservation actions?).

The PA issues and their inefficiency result from human behavioral choices; therefore, their solution requires behavioral changes at different scales. For achieving a long-term conservation, it is compulsory to understand how do the local communities, managers, and policymakers inside and outside the PAs relate with nature, how can they organize, and how can we sell this conservation idea in the future. For this reason, in this document, we aim to introduce three disciplines that could help us to achieve long-term conservation in protected areas: the conservation psychology, the social-ecological system framework, and the conservation marketing.

11.2 Conservation Psychology

> The challenges ahead for biodiversity conservation will require a better understanding of one species: our own. (Saunders et al. 2006)

Most of the programs in PA have been created without considering how the local community relate, feel, speak, and act toward conservation. Despite human actions are complex, behavior is predictable. Knowing the community's physique could aid in developing efficient and long-term conservation programs inside the PAs. In this sense, it is crucial to understand the values, attitudes, concerns, beliefs, and actions of a community toward nature or a conservation program.

Conservation psychology (CP) is a relatively new mission-driven field that emerges from psychologists being worried about the current conservation crisis. In this sense, conservation psychology has a double aim: (1) understanding the behavior of humans toward nature or conservation action and (2) promoting human well-being by developing better conservation strategies (Clayton and Myers 2009;

Saunders 2003). It is a social research, based on the description and experimentation, designed for achieving sustainability. It can focus either on the individual or the collective level. At the individual's level, it searches to understand someone's environmental identity, values, attitudes, or behaviors; meanwhile at the aggregate level, it investigates the social norms and collective actions (Saunders 2003).

The use of CP in PAs would help (1) to understand the personal connections with nature (e.g., Connectedness to Nature Scale (Mayer and Frantz 2004) or Inclusion of Nature in Self (Schultz 2001)), (2) to develop better conservation strategies based on the current values or social norms, (3) to understand the attitudes toward specific conservation program, (4) to enable efficient communication, (5) to evaluate the long-term effectiveness of the conservation action, and (6) to recognize the benefits and barriers in conservation behavior.

Despite these potential benefits, CP is still an underutilized tool for conservation policy (Clayton and Brook 2005). In this section, we will focus on three crucial aspects of CP: values, attitudes, and behaviors.

11.2.1 Values

In psychology, values are desirable goals or end-states, usually stable over time and situations, which serve to a person as guiding principles to evaluate different behaviors, people, or objects (Schwartz and Bilsky 1987). All individuals rank or prioritize their values to form the individual's value system which underlies someone's attitudes and behaviors (Dietz et al. 2005).

Values have been measured either by performing questionnaires or experiments since the last 50 years (for an extended review of values, see Dietz et al. 2005). The Schwartz Value System (SVS) is probably one of the most common way to retrieve the values of the inhabitants in PAs. SVS allow cross-cultural comparisons; this would be specially useful as humans residing inside and surrounding Mexican PAs have different cultural identities (Sarukhán and Larson 2001). The Schwartz Value System includes the application of a questionnaire focusing on the relevance of 56 values as guiding goals of someone's life, using a rating scale from 7 (value is of supreme importance) to −1 (opposed to my values) (Schwartz 1994; Struch et al. 2002). After, researchers preform a multidimensional scaling, traditionally a smallest space analysis (SSA), to obtain each value as a point in a multidimensional space. Values that are similar will have the same rating, and therefore they will appear close to each other inside the SSA. These points tend to be organized in ten different clusters called *motivational value types* such as power, achievement, hedonisms, stimulation, self-direction, universalism, benevolence, tradition, conformity, and security. Furthermore, those ten value types can be classified into four higher order groups (i.e., openness to change, conservation, self-transcendent, self-enhancement) according to their ultimate motivational goals. There is an opposition between these four categories. In this sense, people that care about freedom and detachment (e.g., openness to change) tend to oppose to the values like sense of belonging or stability of society (e.g., conservation). In the same way, people that value ambition and wealth (e.g., self-enhancement) tend to ignore values as the unity of nature or equality (e.g., self-transcendent) (Schwartz 1994; Schwartz and Bilsky 1987; Schwartz and Cieciuch 2016).

Current Western societies tend to follow self-enhancement motivational values (i.e., power and personal achievement) and are reflected in the economic system which threatens biodiversity. To reverse this crisis, values must be shifted to self-transcendent values (i.e., benevolence and universalism) (Martin et al. 2016). However, value systems are reasonably stable, and even if there is an abrupt social-ecological change, they are not entirely replaced by others (Manfredo et al. 2017). Nonetheless, identifying the values of the inhabitants of PAs would assist to understand the actions and attitudes threating the biodiversity and to forge effective long-term conservation strategies (Manfredo et al. 2016). The application of SVS in Mexico has been rare (Arciniega and González 2000; Bilsky and Peters 1999; De-la-Garza-Carranza et al. 2014; Schultz and Zelezny 1998), and none of them focus on understanding the values of the people living in or depending on PAs. Conservation managers could develop better long-term conservation strategies by considering the specific values of each cultural group living or depending on PAs.

11.2.2 Attitudes

Attitude is a latent psychological construct mentally attached to a concrete or abstract object built by affective, conative, and cognitive elements (Breckler 1984; Gifford and Sussman 2012). An environmental attitude is a person's favorable or unfavorable valuation toward the natural environment per se or a conservation action (e.g., reduction of waste, adoption of a conservation program, PA decree) (Kaiser et al. 1999). Therefore, the attitudes toward the environment or a specific conservation program depend on the feelings or concerns, actions or behavioral intentions, and thoughts or beliefs toward nature or toward the objectives and institutions proposing them. It has been argued that attitudes do not determine behavior (Gifford and Sussman 2012). However, they could aid in the identification of possible misinformation in beliefs, conservation behaviors, and the level of public support toward an environmental cause.

The measurement of environmental attitudes toward a specific action or program has been done since the 1970s. This assessment is usually accomplished by the application of scales, questionnaires, interviews, and inventories; nevertheless, they typically have a context-specific design inhibiting cross-study comparisons (Gifford and Sussman 2012; Hawcroft and Milfont 2010). Probably the most common method to retrieve the environmental attitudes is the New Ecological Paradigm scale (NEP) (Dunlap et al. 2000). NEP usually focuses on the agreement and disagreement of 15 environmental-related beliefs, the cognitive element of the attitude, using a scale from 1 to 5 where 5 highly agrees and 1 profoundly disagrees (Dunlap et al. 2000; Hawcroft and Milfont 2010). It is possible to retrieve an average NEP showing the individual or collective pro-environmental attitude. NEP scale has been used in more than 30 countries and 58,279 participants including Mexico (Corral-Verdugo and Armendáriz 2000; Hawcroft and Milfont 2010). Assessing NEP has the advantage of being fast to retrieve and allows cross-study comparisons. Nonetheless, it does not consider the whole multidimensionality of the environmental attitudes.

Another tool for assessing environmental attitudes is the Environmental Attitudes Inventory (EAI) that was proposed by the early 2000s extended in 2010 (Milfont and Duckitt 2004, 2010). EAI searches to understand the beliefs of an individual, or community, towards the environment. According to its latest method developed by Milfont and Duckitt (2010), EAI assesses the multidimensionality of environmental attitudes by using a 120-item questionnaire answered on a 7-point rating scale ranging from 1 (strongly disagree) to 7 (strongly agree). The survey searches the environmental attitude by analyzing 12 specific facets, or primary factors, including the individual's enjoyment of nature, support of conservation policies, activism, confidence in technology, motivation due to anthropocentric concern, eco-centric concern, environmental threats, conservation behavior, utilization of nature, support of population growth policies, dominance over nature, and altering nature. Furthermore, EAI relates the primary factors with a higher dimensional order structure, often called secondary factors of the environmental attitudes, by simplifying the attitudes to either preservation or utilization of nature. Relating EAI to either a preservation or utilitarian attitudes enhances the link between attitudes and values as it can be easily translated into biocentric or anthropocentric values (Kaiser and Scheuthle 2003).

In Mexico, few studies have evaluated the environmental attitudes (Bechtel et al. 2006; Corral-Verdugo and Armendáriz 2000; Schneller et al. 2015; Schultz and Zelezny 1999), and none have focused on the individuals living inside or around PA. The systematic application of NEP and EAI tests to the communities inside PAs could assist in the identification of possible promoters (early adopters) and detractors (laggards) of a conservation program and would enable cross-study comparisons. Still, it would be recommended to develop a novel attitude test explicitly designed for Mexican PAs to ensure asking relevant questions that assist in the elaboration of more efficient long-term conservation strategies.

11.2.3 Behavior

Human behavior (e.g., inaccurate decision-making) is the principal cause of the environmental problems. Therefore the conservation solutions rely on changing behavior. PA evaluation rarely considers the understanding of human behavior, but if conservation means behavior (Schultz 2012), conservation psychologists should play a crucial role in the design, implementation, and evaluation of conservation programs inside PAs.

Human behavior has multiple causes. Despite behavior is not always rational, meaning that people sometimes act against what is on their best benefit, there is a logical pattern in their actions so that it can be predicted. There are plenty of theories to explain behavior, but probably the most relevant to understand conservation behavior is the Theory of Planned Behavior (Ajzen 1991) and Value-Belief-Norm Theory (Stern et al. 1999). According to Ajzen (1991), a person will be more likely to engage in a conservation program if the individual (1) believes that his/her inner circle would approve that behavior (i.e., subjective norm), (2) perceives the behavior as easy (i.e., perceived control), and (3) has a favorable valuation toward conservation program (i.e., attitude). Instead Stern et al. (1999) propose that an individual will engage in a conservation program if this action agrees with their values and beliefs that there are negative consequences of not joining to the program (i.e., awareness of consequences) and that its activities are likely to have a positive impact (i.e., the ascription of responsibility). Those values and beliefs create a duty to act (i.e., norm) in the conservation program. Using these theories could help us to understand why some people play an active role in conservation and others do not.

Fortunately, the behavior is susceptible to change. If there is a shift on the values, attitudes, or social norms or there is a decrease in the barriers or an increase in the benefits, people are likely to change their behavior (Steg and Vlek 2009). However, promoting conservation behavior is a challenge.

Evolutionary psychologists believe that the ineffectiveness of several conservation programs arise from the mismatch between the world where humans evolved and the current world. In this sense, the adaptive behavior that enables humans to survive and thrive during their evolution could also explain the reason why humans do not engage in conservation behaviors. For this reason, if conservation programs in PA aim to reach a long-term effectiveness, they must consider five evolutionary human biases: (1) the propensity of self-interest, (2) the motivation of relative status over absolute, (3) the proclivity to imitate, (4) the predisposition to focus on short-sighted benefits, and (5) the tendency to discard impalpable to ensure long-term actions (Griskevicius et al. 2012; Van Vugt et al. 2014).

Effective conservation strategies would be more efficient if they match with the evolutionary mechanism driving the problem. For example, if conservationists aimed at mainstreaming the Wildlife Management Unit program (UMA; see Table 11.1), it would be necessary (1) to create interdependent UMA network enhancing the self-interest, (2) to encourage competitions between different UMAs by ranking the most effective ones improving the motivation for relative status, (3) to depict the numerous UMAs installed in the country to promote the social norm, and finally (4–5) to emphasize current and local benefits of establishing an UMA.

The study of conservation psychology has not only identified values, attitudes, and behaviors in different countries. It has also recognized several tools to promote behavioral changes. Incentives, competitions, education, prompts, feedbacks, cognitive dissonance, social norms, convenience, and commitments are tools that have been proven effective to provoke changes in behavior (Mckenzie-Mohr 2000; McKenzie-Mohr and Schultz 2014). Schultz (2014) made an excellent review of the effectiveness of these strategies promoting sustainable practices. As seen in Table 11.1, most of the conservation programs in PAs depend on giving incentives. Research on conservation psychology, social-ecological systems, and conservation marketing has demonstrated that incentives are a useful tool in changing behavior in a short term; however, they do not reduce the conservation threats in the long term, and they usually discourage other conservation behaviors (i.e., if I am not paid, why should I do it) (Evans et al. 2013).

PA managers should use these tools to reduce or change the unsustainable behaviors and to increase the adoption of the current conservation programs. Managers should aid from conservation psychologists and marketers to design of *when* and *where* to use each strategy and evaluation of an effective long-term conservation program. CP may also assist in recognizing the values, attitudes, and behavior that allow the community to organize themselves and form new types of governance. Some of these tools will be further discussed in following sections of *Social-Ecological System Framework* and *Conservation Marketing.*

11.3 Social-Ecological System Framework

> There is no reason to believe that bureaucrats and politicians, no matter how well-meaning, are better at solving problems than the people on the spot, who have the strongest incentive to get the solution right. (Elinor Ostrom).

Conservation programs in PAs are complex. Each PA has a different social, ecological, economic, and political context. In this sense, the interaction between these components will differ according to each temporal and spatial scale (Agrawal and Ostrom 2006; Ostrom 2007). Ostrom's social-ecological system framework (SESF) is useful to understand and model the interactions between these components and the possible outcomes of each conservation program by identifying, organizing, and simplifying relevant factors and variables of the SES (Schlager 2007).

Since the past decade, the form of governing the environment has changed dramatically due to empirical failure. The common theory demonstrates that controlling the resources from the state (i.e., state theory and command-and-control governance) is inefficient in the long-term compared to the collective action. Therefore, it is necessary to build up more collaborative and nonlinear conservation programs, to involve all actors (e.g., state, communities, civic organizations) to engage on a hybrid form of governance (Berkes 2004; Lemos and Agrawal 2006).

SESF might be especially relevant for Mexican PAs. The populations that live within and surrounding PAs are predominantly rural (<2500 inhabitants) and are dispersed into small communities with the highest marginality and poverty indexes (CONEVAL 2016). Usually, these populations already have systems of governance based on common land tenure (e.g., *ejidos* and communities) where the resource units are the material, social, and cultural basis of their livelihood (Boege 2009; Cumming and Allen 2017). Furthermore, common land tenure represents 60% of the national territory of all Mexican PAs (Bezaury-Creel and Gutiérrez-Carbonell 2009), where 26.3% are the property of indigenous groups (Boege 2009). This form of land tenure generates a patrimonial perspective because land cannot be transferred to a single individual allowing (1) a stronger communal-environmental identity (Sarukhán and Larson 2001) and (2) the emergence of particular forms of governance and organization (e.g., the assemblies). In the assemblies, each owner can participate in the planning and management of the territory, and, because of that, the rules-in-use for the appropriation of their collective resources are diverse and function under different institutional arrangements in each community (Aguilar et al. 2011; Boege 2009). Thus, to understand the economic and social context, as well as, the way the community appropiates the natural resources given the particular ecological dynamics is crucial to ensure the long-term effectiveness of each PA (Hansen and DeFries 2007).

The SESF aims to systematically analyze the complexity of SES as a diagnostic approach to understand small-scale environmental governance (Ostrom 1990). In other words, the SESF focuses on understanding the set of regulatory processes by which individuals, organizations, and political actors **create rules** to influence behavior and biological outcomes (Lemos and Agrawal 2006). These rules interact in an intricate pattern, where the removal or reinforcement of one rule may affect the whole governance outcome (Cox 2011). The SESF is a nested framework that integrates cumulative knowledge on variables and their effects on environmental governance and sustainability (Cumming et al. 2015; Epstein 2015). Applying SESF in PAs could aid in understanding how to build efficient long-term conservation programs.

11.3.1 Method

The SESF as a tool helps to organize the social and ecological variables that are relevant to each SES. Traditionally, the SESF considers four core components: (1) resource system (e.g., fishery, forest), (2) resource units (e.g., fish bank, wood), (3) users (e.g., local community), and (4) governance system (e.g., rules, institutions, government). Each core component can be unpacked in second-tier variables. For example, for the resource unit component, some of their second-tier variables are the mobility, growth, and replacement rate of the unit or for the governance system the collective choice rules, property rights system, and governmental and nongovernment institutions (for further insight on the variables in each component, see Ostrom 1990). A virtue of SESF is that each manager could include different second-tier variables if it considers it necessary.

The four core components and their second-tier variables interact with each other. The possible interactions can benefit the environment and promote the collective action (e.g., networking activities, information sharing among users) or obstruct them (e.g., conflict among users, differential investment activities). The specific moment of those interactions is called action situations and when they happen arose different outcomes (e.g., social equity, ecological resilience, overharvest) (McGinnis and Ostrom 2014).

SESF recognizes the PA as a complex and open system, therefore, it considers the possible feedbacks between the outcomes and the four components, as well as, the relationship between the external social, economic, and political settings (e.g., government resource policies, economic development) and related ecosystems (e.g., climate and pollution patterns) with the social-ecological system (McGinnis and Ostrom 2014; Ostrom 2007, 2009).

The application of SESF has shown that co-management between the government and the local community is the most efficient way to conserve. To engage the community's participation in conservation programs, PA managers should (1) examine the links between resource management, social organization, and property right systems, (2) acknowledge the traditional institutions built by resource users and complement with scientific knowledge, (3) recognize different forms of relationship with nature other than the Western perspective, (4) analyze power relationships among actors in the made decision and shared benefits in relation to political agendas, (5) interpret the landscape as historical processes for understanding the ecological sense of actual resource use practices, and (6) integrate economic view and values as a subset of the environmental system in long-time periods (Berkes 2004). By considering these variables, conservation programs will avoid conflicts related to the replacement or subsume of pre-existing communal management regimens (Alcorn and Toledo 1997) and allow the empowerment, equity, and distribution of the benefits between the different users (Agrawal and Gibson 1999; Berkes 2004).

11.3.2 Advantages of SESF for Long-Term Conservation in Mexico

SESF can be a powerful tool with several advantages for managing social-ecological systems as PAs (McGinnis and Ostrom 2014; Ostrom 2007, 2009). First, the SES is a holistic framework allowing cross-cultural comparisons (Berkes 2004). Second, SESF allows to find familiar typologies of governance and facilitates the identification of critical variables for achieving long-term conservation (Basurto et al. 2013; Basurto and Ostrom 2009; Cumming and Allen 2017; Thiel et al. 2015). Third, PA managers could detect systematically the components or variables that inhibit the capacity of self-organizing for achieving conservation by implementing this framework in different case studies (Basurto et al. 2013). We will propose that conservation managers design a useful generic framework for federal PAs that could be adapted for each PA. In this sense, it would be necessary to select and explicitly define the relevant second-, third-, fourth-tier variables to explain and characterize PA governance.

11.4 Conservation Marketing

> Conservation is primarily not about biology but about people and the choices they make. (Balmford and Cowling 2006)

Marketing is a practical discipline that focuses on the relationship between consumers and the products. It aims not only to describe how transactions between the consumer and the producer are created, facilitated, and stimulated by value offerings but also to obtain specific responses in consumers through the creation and offering of values (Kotler 1972). The role of marketing is to promote an efficient communication between producers (i.e., product) and consumers. Marketing analyzes this consumer-producer relationship by focusing on four components: (1) product design, (2) pricing, (3) place (e.g., distribution), and (4) promotion (i.e., communication) strategies (Kotler 1972). Effective marketing is an evaluative process that arises from analyzing the consumers' demands, designing a successful product, organizing the distribution, and evaluating the marketing efforts.

Most marketing focuses on products (i.e., goods and services) that are tangible and that have clear property rights for the producers and apparent benefits to the consumers. Nonetheless, since the 1960s, social marketing uses common marketing tools with the objective to sell, as a product, an idea or a behavioral change for social good (Andreasen 2003; Kotler and Levy 1969). For example, an NGO (i.e., organization) aims to improve the quality of life of the fertile public (i.e., consumers or target audience) by promoting the birth control (i.e., product). This technique has been proven effective in shifting behavior to increase the community's health and security (for an extensive review on this topic, read Stead et al. 2007).

Conservation marketing is the use of social marketing tools to promote a behavioral change to reduce unsustainable habits and the current threats to biodiversity (Smith et al. 2010). In this sense, the behaviors (i.e., products) CM sells are the protection of the environment and sustainable development. As it is a practical discipline, it uses several techniques and findings from social (e.g., conservation psychology) and biological research (e.g., ecology) to plan, implement, and evaluate its marketing plan.

The success of a CM strategy relies on understanding and segmenting the target audience (e.g., gender, age, values, attitudes), selecting end-state desirable behaviors (e.g., that would directly cause a decrease of the conservation's threat), developing a strategy that understands the audience context (e.g., barriers and benefits to engage to the selected behavior), removing the obstacles, evaluating the results, and building a relationship with the intended audience (e.g., promoting a fidelity loop) (Mckenzie-Mohr 2000; Wright et al. 2015).

There is plenty of research concerning conservation marketing and community-based social marketing. In Mexico, conservation marketing is increasing and is mainly being used by environmental NGOs (e.g., WWF and RARE) and governmental institutions (e.g., CONANP) to produce a behavioral change in inhabitants of the PAs. Probably the best application of CM in Mexico is the detection of flagship species, the Pride Campaigns, and the building of brands of sustainable products developed in PAs.

11.4.1 Flagship Species

A flagship species is a charismatic species that conservation managers use as a symbol to raise awareness about biodiversity loss. The purpose of such species is to maximize the impact on the targeted audience and to raise funds for conservation actions. In this sense, the term is not related to its ecological role or threatened status (Smith et al. 2010). For this reason, Verissimo et al. (2011) define a flagship species as "a species used as the focus of a broader conservation marketing campaign based on its possession of one or more traits that appeal to the target audience." The selection and promotion of a flagship species do not depend on its ecological characteristics nor represent biodiversity better than selecting another species at random (Williams et al. 2000). The use of flagship species is prevalent inside the Mexican PAs.

Managers at CONANP should be careful at denominating flagship species. Unplanned arousal of flagship species could detriment the ecosystem's conservation by favoring strategies toward a single species or by creating resentment between the community (Walpole and Leader-Williams 2002). Verissimo et al. (2011) proposed a seven-stage flagship species selection framework that elects this species through the analysis of the relationship between the conservation issue, the target audience, and the possible flagship species. Despite that favorite flagship species include big-sized furry animals with eyes facing forward (e.g., apes, big cats, and pandas) which might not be present in all PAs, research inside PAs should aid to identify a currently overlooked charismatic species, or *Cinderella species*, that could assist in raising conservation awareness (Smith et al. 2012). In the rare case, a PA lacked a charismatic species; marketing campaigns could focus on noncharismatic species (e.g., rodents and toads) and still raise funds and awareness (Veríssimo et al. 2017).

As every marketing campaign, it is compulsory to assess the effectiveness of the flagship species. This can be done by performing surveys to the target audience about the recognition (i.e., what species do you recognize or recall?), the appeal (i.e., do you find it charismatic?), and the protection (i.e., how can we protect this species?) (Veríssimo et al. 2014). Another way to assess its effectiveness is by measuring the number of people that join the conservation program or the amount of money raised after the campaign.

11.4.2 Pride Campaigns from RARE

Probably the most useful example of conservation marketing in PAs is the Pride Campaigns from RARE. RARE believes that people are connected to nature, but because of complicated reason, people sometimes behave in unsustainable ways (RARE n.d.-b). RARE developed a conservation marketing strategy to that considers six phases: (1) engaging stakeholders, (2) understanding the context, (3) rating the conservation threat, (4) mapping the problem, (5) creating a theory of change, and (6) evaluating the results (for further details, see RARE n.d.-a, -b). During the fifth step, conservation marketers plan, implement, and evaluate the desired strategy for the behavior change. The theory of change includes the assessment of the knowledge (beliefs) and attitudes of the community, the promotion of places where the targeted audience can interchange communication, the removal of the behavioral barrier, the enhancement and evaluation of the behavioral change, and its effects on reducing the conservation threat (RARE n.d.-b). Pride Campaigns uses different tools to produce the behavioral change. The strategies used by RARE include social modeling and social norms to improve motivation and the creation of flagship species and education to increase awareness. All strategies are adapted to specific target audiences.

Managers of Mexican PAs have already recognized the relevance of Pride Campaigns for achieving behavioral changes. For example, *Pronatura* and RARE led a conservation marketing Pride Campaign to reduce the deforestation rate of the costal lands of Veracruz (i.e., threat) to conserve this habitat for migratory birds (e.g., falcon). The campaign aimed to increase the amount of voluntarily conservation areas decrees (i.e., product) by the landowners of the region (i.e., target audience). To do that, there was a conservation marketing strategy to increase the knowledge and awareness about the benefits of protecting the land and removal of the barriers to perform this certification. The campaign used the falcon as flagship species. At the end of the Pride Campaign, 14 landowners join their lands in the voluntary conservation areas, protecting more 1500 ha for the following 10 years (Balcazar-Arias 2010). Other successful examples of the application of RARE in Mexican PAs include the use of flagships species as the prairie dogs (*Cynomys mexicanus*) in Llano la Soledad (Lopez Ventura 2007), the grouper (*Epinephelinae*) in Sian Ka'an, the common snook (*Centropomus undecimalis*) in La Encrucijada, the quetzal (*Pharomachrus mocinno*) in El Triunfo (Contreras et al. 2001), the "sotolin" (*Beaucarnea gracilis*) in Tehuacán-Cuicatlán (Beléndez-Hernández 2008), and the "viejito" cactus (*Cephalocereus senilis*) in Metztitlán (Sánchez-García 2008).

11.5 Conclusions

The problems of conservation are complex. They involve different actors, interests, and scales; consequently, their solution must recognize this multiple level interaction to achieve long-term goals (Ostrom 1990, 2007). The use of social disciplines and theories, as conservation psychology, environmental governance, and conservation marketing, in the design, implementation, and evaluation of PAs would improve its management (Bennett et al. 2017). Up to now, tools have not been fully involved in helping to address conservation threats (Clayton and Myers 2009). However, we believe that conservation managers could reinforce their strategies by applying them to ensure effective long-term conservation.

Social ineffectiveness found in Mexican PAs could be related to the form the conservation programs are designed. Mexican conservation programs were created in a *top-down* scheme aiming to solve the conservation problem or to reduce the threat as fast as possible. Table 11.2 gives a summary of the potential tools to investigate how human relates to their environment. We believe this information would be crucial to design target-specific programs. For example, to stop habitat loss and fragmentation, the PROCODES program gives subsidies to the landowners as payment for the

Table 11.2 Social disciplines and tools that are relevant for long-term conservation

Discipline	Social tools	Aim	Target groups
Conservation psychology	Connectedness to Nature Scale (CNS) and Inclusion of Nature in Self (INS)	Determine individual's affections, experiential connection to nature	Individuals, the local community inside PAs, external population threating PA conservation
	Schwartz Value System (SVS)	Determine the personal motivations that are driving someone's actions	Individuals, the local community inside PAs, external population threating PA conservation
	Environmental Attitudes Inventory (EAI) and New Ecological Paradigm scale (NEP)	Determine the environmental attitude, or the favorable or disfavorable evaluation, attached to nature or conservation program	Individuals, the local community inside PAs, external population threating PA conservation
	Theory of Planned Behavior (PB) and Value-Belief-Norm Theory (VBN)	Understand the reasons for unsustainable or conservation behaviors	Individuals, the local community inside PAs, external population threating PA conservation
	Psychological evolutionary biases (PEB)	Design better conservation programs fit the human's psychological, evolutionary biases	Individuals, the local community inside PAs, external population threating PA conservation
Social-ecological system framework	Mapping social-ecological systems	Diagnose case studies to propose governance interactions that have to be improved for long-term sustainability	Cross-scale institutions, between local and national scales
	Community-based conservation	Promote horizontal planning and management of conservation programs to empower local people and promote their engagement in sustainability conservation	Individuals, the local community inside PAs, external population threating PA conservation
Conservation marketing	Flagship species	Raise awareness, change attitudes, and promote behavioral change by selecting useful charismatic species	Local and external community of PAs
	RARE Pride Campaigns	Promote the behavioral change and adoption of a conservation program by using enhancing the pride related to the natural capital of the communities	Local community inside PAs

ecosystem services provided by the conservation status of their habitat. This program searches to stop habitat loss in the short term, because, despite ending the threat and provoking a conservation outcome, the program does not consider the long-term biological effects and the social feasibility (e.g., founding). This type of reactive conservation strategies needs to be perpetually applied to have an impact; in such cases, even if the species' extinction risk may be reduced (e.g., by increasing its survival and/or reproduction) in few generations, the program's associated costs may render it financially unsustainable, and ultimately the species would return to its endangered status after management actions are terminated (Cardador et al. 2015; Torres-Orozco et al. 2016). As PROCODES, most of the conservation programs in Mexico depend on subsidies, which are inefficient for achieving long-term conservation benefits and do not advocate to change people values, attitudes, and behaviors after the program has stopped. Therefore, we suggest that conservation programs in PAs might be conservation traps instead of conservation solutions.

To avoid funding possible conservation traps, conservation strategies should advocate changing the values, attitudes, and behaviors of the population that live inside or in the surroundings of PA and of the society in regional and national scales (Fig. 11.1). We believe that Mexican conservation managers in PAs are doing exceptional work and that the inclusion of social disciplines and tools as presented in this chapter would allow reaching to long-term conservation.

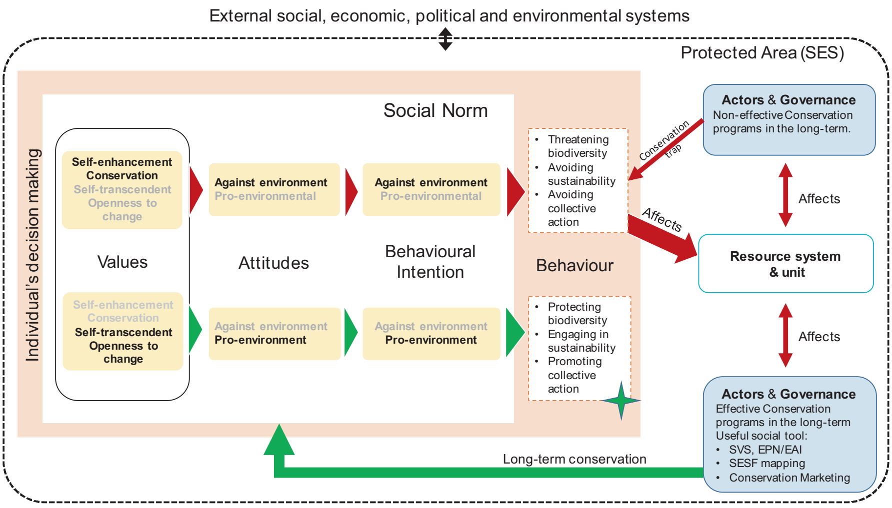

Fig. 11.1 Understanding human behavior to improve the conservation programs long-term efficiency inside PAs. Protected areas are social-ecological systems (SES, external dotted line) embedded in external social, economic, political, and environmental systems. Each PA has different actors, governance, resource system, and units. Individual's unsustainable actions emerge from self-enhancement values (e.g., power and ambition), disfavoring nature or conservation programs (e.g., attitudes), having behavioral intentions against the environmental protection, and believing the other people act unsustainably (e.g., social norm). That unsustainable behavior affects the resource unit and its system provoking the decrease or depletion of the resource unit (red arrows). Actors and governance may design, apply, and evaluate two types of strategies to change the threatening behavior: (1) short-term goals conservation programs (e.g., reactive programs based on subsidies) that might act as conservation traps (red feedback loop at the right top corner) or (2) long-term goals conservation programs that search to promote self-transcendent values, pro-environmental attitudes, and behavioral intentions by applying proactive programs considering the Environmental Attitudes Inventory (EAI), the social-ecological system framework mapping (SESF), and conservation marketing to meet long-term pro-environmental behaviors (green arrows) (*SVS* Schwartz Value System, *EPN* New Ecological Paradigm scale)

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Chapter 12
Estuaries and Coastal Lagoons of Mexico: Challenges for Science, Management, and Conservation

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Abstract The Mexican coastal area is made up of a mosaic of scenes along a coastline of ~11,200 km where estuaries and coastal lagoons represent an integral and important part with ~15,673 km^2 of surface area. This contribution summarizes and integrates information from these ecosystems on the factors that explain its diversity, knowledge of environmental condition in terms of eutrophication and contamination by trace elements, and conservation efforts considering protected areas decreed and presents opportunities and challenges for research, conservation, and management. Diversity estuaries and coastal lagoons are explained by the influence of different climatic regions, geologic origins, tide conditions, precipitation rates, rates of evaporation, wind patterns, and water masses. These systems exhibit a spectrum of environmental conditions from pristine to eutrophication and pollution problems. The challenge is to establish a national program of estuaries and coastal lagoons that allows to integrate and systematize the knowledge gained as well as an agenda of research, monitoring, and management of selected and representative systems of all regions of the country, where the coastal lagoons that are already part of natural protected areas can be part of this selection.

Keywords Estuaries · Coastal lagoons · Mexico

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12.1 Introduction

In this study the definitions of estuarine and coastal lagoon proposed by Kjerfve (1994) are as follows:

Estuary: an inland river valley or section of the coastal plain, drowned as the sea invaded the lower course of a river during the Holocene sea-level rise, containing seawater measurably diluted by land drainage, affected by tides, and usually shallower than 20 m.

Coastal lagoon: an inland water body, usually oriented parallel to the coast, separated from the ocean by a barrier, connected to the ocean by one or more restricted inlets, and having depths which seldom exceed a couple of meters. A lagoon may or may not be subject to tidal mixing, and salinity can vary from that of a coastal freshwater lake to a hypersaline lagoon, depending on the hydrologic balance. Lagoons formed as a result of rising sea level during the Holocene or Pleistocene and the building of coastal barriers by marine processes.

These two categories of coastal water bodies differ geomorphically but are related in ecological terms (Margalef 1969) and characterized by (1) existence of ecological gradients due to the transition from marine to the continental domain, and these biological, hydrological, and sedimentological gradients form complexes of different mosaic habitats promoting environmental heterogeneity in the ecosystem as between adjacent ecosystems (e.g., food web connectivity, interface with the adjacent sea basins, etc.) (Cataudella et al. 2015). (2) They are variable systems in space and time, with cyclical swings from periods (glacial-interglacial) to days (tidal cycle), passing seasons, and yearly cycles, and this environmental variability is influenced by climate, geomorphology, wind, rainfall, runoff rivers, and tidal and coastal circulation (Phleger 1981; Wolfe and Kjerfve 1986). (3) They provide high rates of gas exchange, import and export energy in the form of organic carbon, import energy from land or sea, and export energy due to high production within the system, such as the import, transport, process, and export of nutrients in all their forms (Heip et al. 2011). (4) They have high productivity, caused by the contribution of various types of primary producers, tidal power and circulation, the abundance of nutrients, and preservation, retention, and efficiency of nutrient recycling between benthic and pelagic habitats (p. 188 Alongi 1998; McLusky and Elliot 2004). (5) They are a land-sea system of confluence providing diverse habitats for breeding, feeding, or shelter for many species of invertebrates, fish, birds, reptiles, and marine mammals, resident or dependent on these systems at some stage of their life cycle (Cowan et al. 2013; Greenberg 2013). (6) And they provide ecosystem services: nutrient recycling, providing raw materials, providing coastal protection, sustaining fisheries, tourism, recreation, and promoting education and scientific research (Barbier et al. 2011).

These water bodies are a valuable natural capital. Adjacent areas provide favorable conditions for agriculture and tourism on the one hand sectors, as well as fisheries and aquaculture on the other (Gönenç and Wolflin 2005), which has proved attractive for the establishment of human settlements and also a challenge for use, management, and preservation.

In Mexico, estuaries and coastal lagoons are an integral and important part of the coastal scenery covering ~15,673 km^2 along 11,593 km of coastline, including the Pacific coast (8475 km) and the Gulf of Mexico and Caribbean Sea (3118 km) (Lara-Lara et al. 2008). De la Lanza-Espino et al. (2013) reported 164 coastal lagoons (Pacific, 76; Gulf of Mexico, 88) and 27 estuaries (Pacific, 19; Gulf of Mexico, 8).

In Mexico, outstanding contributions to the knowledge of coastal lagoons and estuaries can be traced to the *Coastal Lagoons: A Symposium – Memoir of the International Symposium on Coastal Lagoons (Origin, Dynamics and Productivity)*, made in 1967 (Ayala-Castañares and Phleger 1969), a publication of Lankford (1977) which describes and classifies Mexican coastal lagoons for their geological origin, *Mexican Coastal Ecosystems* (Contreras-Espinoza 1993), and *Coastal Lagoons and the Mexican Coast* (De la Lanza-Espino and Cáceres-Martínez 1994). The most important collection of scientific information concerning these coastal ecosystems in Mexico has been compiled in a commendable effort by the Documentation Center "Mexican Coastal Ecosystems" available at http://investigacion.izt.uam.mx/ocl/index2.html.

This contribution summarizes and integrates scientific information from coastal lagoons and estuaries of Mexico for the purpose of disclosing:

1. The factors that explain its diversity, with an ecosystem approach using ecological and hydrodynamic criteria following the regionalization of Lankford (1977) and applying restriction and saline indices proposed by Chubarenko et al. (2005)
2. Coastal lagoons and estuaries including protected natural areas to meet the representativeness of these ecosystems in the national context
3. Knowledge of environmental condition from the studies that have addressed the process of eutrophication and contamination by trace elements
4. Based on the above items, present opportunities and challenges for research, conservation, and management of these coastal ecosystems

12.2 Diversity of Estuaries and Coastal Lagoons

The classification of the coasts of Mexico has been carried out following two approaches: (1) inventory of coastal forms based on their genesis in terms of geotectonic, geomorphological, climatic, and landscape aspects and (2) ecosystem approach.

Based on the first approach, the pioneering study of the classification of the Mexican coast was done by Carranza-Edwards et al. (1975) where they proposed nine morpho-tectonic units based on the classification tectonics of Inman and Nordstrom (1971) and genetic classification geomorphology of Shepard (1973).

Lankford (1977) subdivided the Mexican coast into seven regions by a classification system based on the tectonic origin linked to the history of sea-level change in the Holocene and climate, where 123 coastal lagoons are recognized.

Álvarez-Arellano and Gaitán-Morán (1994) established six coastal regions using criteria based on:

1. *Hypsometry*, to evaluate the association of water bodies with the proximity of plains and mountain ranges
2. *Regional bathymetry*, which reflects the tectonic association with wide or narrow continental shelves
3. *Regional geology* identifying geological formations as a source material supply clastic-biogenic or in nine morpho-tectonic units
4. *Hydrology*, where the magnitude of runoff from watersheds into the sea is identified
5. *Weather*, where four climatic regions were identified based on the room temperature and the annual amount of precipitation
6. *Tides*, where three regions are grouped into three regimes based on criteria of Davies (1964) as microtides, mesotides, and macrotides

The application of the above criteria resulted in 97 coastal lagoons.

De la Lanza-Espino et al. (2013) recognize five regions that associate the watershed to its fluvio-maritime system and climate; as a result of applying these criteria, they found 164 coastal lagoons, 27 estuaries, 90 bays, and 304 streams, adding 585 coastal water bodies to the Mexican coast. It is important to consider that the wetlands are defined as channels associated mainly with intertidal coastal lagoons. The results of these contributions beyond quantitative differences associated with the particular criteria used exhibit prevalence and a significant amount of coastal lagoons that are of interest to understand their diversity and environmental condition.

The ecosystem approach to show the diversity of coastal lagoons in the country was using the morpho-hydrodynamic criteria combining regionalization of Lankford (1977), which have been widely accepted, with parameters such as the restriction and salt indices given by Chubarenko et al. (2005).

Based on the regionalization proposed by Lankford (1977), six climatic types and three types of coasts depending on the tidal amplitude are recognized: macrotidal in upper Gulf, mesotidal in most Mexican coasts, and microtidal in the Gulf of Mexico and Caribbean Sea (Fig. 12.1).

The climatic types that influence Mexican coastal lagoons are distributed in latitudinal sense because of the distribution of temperature and precipitation. In Mexico's arid, semiarid, and temperate climates with dry winter, they are confined to the north of the Tropic of Cancer. The northern part of the Pacific coast has a Mediterranean climate influenced by the cold California Current. The wet and humid tropical climates, in which dry climate is predominant, are confined to the south of the Tropic of Cancer; these climates are present in the southern Pacific coast (Zone D), southern Gulf of Mexico within the region E, Yucatan Peninsula, and the Caribbean (Fig. 12.1).

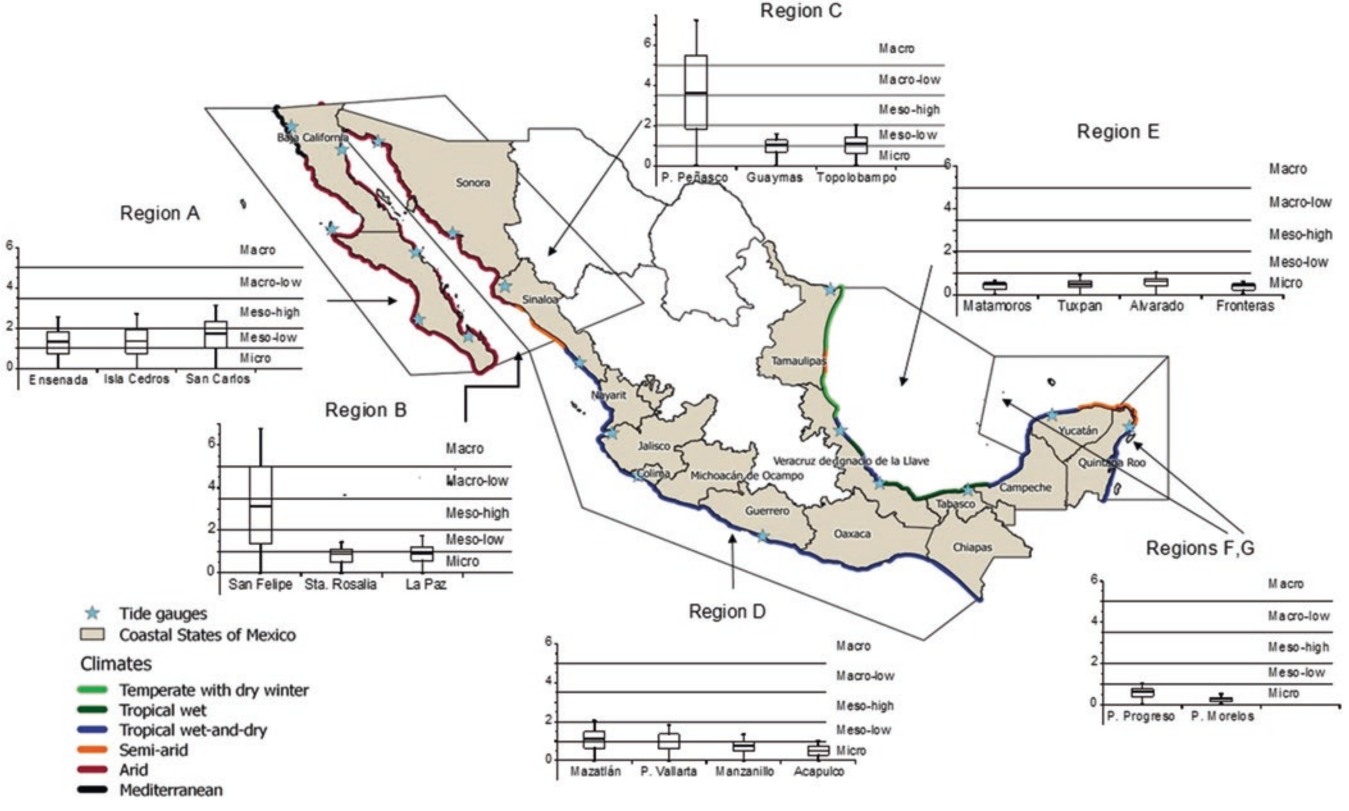

Fig. 12.1 Map of Mexico showing the coastal regions and their tidal ranges according to Lankford (1977) and the types of climate that influence the coastal zone. The limits of the coastal states of Mexico are indicated

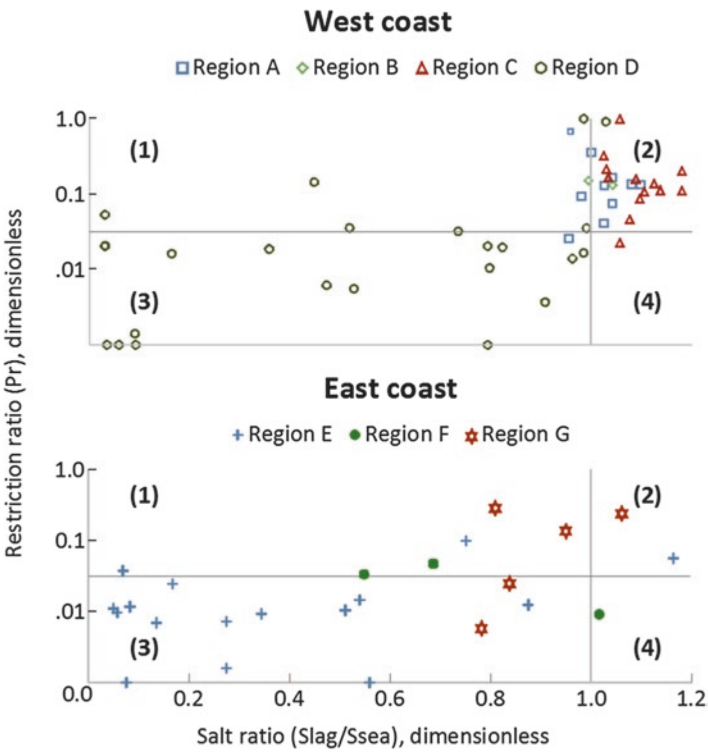

Fig. 12.2 Comparative analysis of Mexican coastal lagoons (n = 82) based on the morphology expressed as a restriction index (Pr) with the water exchange capacity expressed as a saline index, which indirectly determines the climatic influence by rainfall and runoff in according to criteria from Chubarenko et al. (2005). The numbering in the graph corresponds to (1) leaky lagoons with high influence of freshwater, (2) leaky lagoons with high influence of seawater, (3) choked lagoons with high influence of freshwater, and (4) choked lagoons with high influence of seawater. Sources: http://investigacion.izt.uam.mx/ocl/mapa.html; http://nest.su.se/mnode/wmap.htm

The climatic regionalization has a strong influence in the levels of salinity in the gaps; however hydrodynamic properties thereof (e.g., induced tidal flow) and morphological conditions expressed as constraint index also play a major role.

On the west coast of Mexico, climate latitudinal gradient correlates with the salt index which shows that regions A, B, and C correspond to hypersaline lakes north of the Tropic of Cancer while gaps in the subtropical region D are mesohaline. On the East Coast, the latitudinal differences are also very marked where the gaps with most freshwater influence are the E region associated with tropical humid climate while regions F and G tend to have hypersaline conditions (Fig. 12.2). This is consistent with what was observed by Contreras-Espinoza and Warner (2004) which classifies these water bodies according to their salinity.

The morphological gradient indicated by the restriction index (Pr) indicates that gaps in the regions D and E tend to be associated with runoffs and are restricted lagoons due to extensive growth of sandy barriers and tidal channels favored by deltaic sedimentation. Gaps in the regions A, B, and C of the West Coast and gaps in the regions F and G of the East Coast are gaps with marine influence as they have less sediment.

This comparative analysis of Mexican coastal lagoons exposes their diversity and suggests the importance of considering the classification of coastal lagoons exposed in contributions of Kjerfve (1986), Kjerfve and Magill (1989), and Kjerfve (1994). This classification is implicitly an ecosystem approach to coastal lagoons and groups them into three geomorphological types considering water exchange with the ocean, in order of lowest to highest interchange: (1) choked, (2) restricted, and (3) leaky. This has great significance, because the rate and magnitude of ocean exchange functions reflect the dominant force and the timescale of hydrological variability. The rationale is that the gaps are influenced mainly by tidal freshwater input and winds, and local hydrodynamics answers to each of these factors depending on the magnitude of water exchange with the adjacent sea which is controlled by the characteristics of their mouths and channels of communication with the sea.

In particular, choked lagoons generally found along coasts with high wave energy and significant longshore transport are characterized by one or more channels of long narrow inlet, water residence for prolonged periods, and dominant wind forces; intense solar radiation coupled with water influx events can cause vertical stratification. This type of lagoons is common on the coasts of Oaxaca and Chiapas in the south. The restricted lagoons generally have two or more input channels or mouths and have well-defined circulation tides that are strongly influenced by wind and are generally vertically mixed. This type is characteristic lagoons on the coast of southern Sonora and northern Sinaloa.

The leaky lagoons typically are found along the coast where the currents are the most important tidal sediment transport in the waves by winds; they are characterized by large tidal range, extensive exchange with ocean, strong tidal fronts, and the existence of turbidity and salinity. Such gaps are found in the northern Gulf of California.

12.3 Eutrophication

In the three International Symposiums on Research and Management of Eutrophication in Coastal Ecosystems conducted in 1993, 2006, and 2010, all based in Denmark, it has been recognized that coastal eutrophication has challenged scientific research and environmental management.

Since the definition of eutrophication "increase in the rate of supply organic matter to an ecosystem" (Nixon 1995) to the evolution of the concept (Cloern 2001; Howarth and Marino 2006), there have been many contributions to specific topics about causes, recycling nutrients, nutrient limitation, reference conditions, association with other pressures (e.g., climate change), monitoring strategies, modeling, and adaptive management (Andersen and Conley 2009).

Importantly, evidence of complex responses of coastal ecosystems to nutrient reduction requires management goals and policies wherein support is reconsidered; this forms the recognition of the complexity of ecosystem responses, including non-linear responses and thresholds observed in responses (Duarte 2009). It is also important to not only see eutrophication as a simple problem of contamination by nutrients but, actually, as an increase in the rate of supply of organic matter to an ecosystem; this implies that eutrophication is primarily a change in the energy base that can spread through the ecosystem in different ways and produce a variety of changes (Nixon 2009).

Excessive intake of nutrients from human activities and inducing the process of eutrophication are considered one of the engines of global change (Andersen et al. 2006; Valiela 2006). Based on multiple studies worldwide and different methodologies, knowledge about eutrophication has been generated mainly in temperate lakes and oligotrophic systems (Varona-Cordero et al. 2014), being less studied tropical and subtropical lagoons, where it is estimated that the rate of nutrient supply increases (Galloway et al. 2004) and the effects of eutrophication may be more severe (Corredor et al. 1999).

In developed countries, environmental government agencies develop methodologies that will apply throughout their territory and carry out a detailed plan to protect, assess, and monitor the negative effects of coastal eutrophication (Devlin et al. 2011). It is necessary to apply them in Mexico, where efforts to understand the eutrophication are limited, isolated, and discontinuous, despite the recognized socioeconomic and ecological value of coastal lagoons and estuaries.

Various methodologies have been proposed for assessing coastal eutrophication worldwide; Mexico has used only six indices and one model: Karydis (Karydis et al. 1983), Ignatiades (Ignatiades et al. 1992), OECD (OECD 1982), Carlson (Contreras-Espinosa et al. 1994), TRIX (Vollenweider et al. 1998), AZCI (Mendoza-Salgado et al. 2005), and ASSETS (Bricker et al. 2003) (Fig. 12.3). The choice has been mainly based on the information requirements of each methodology, sampling effort required to generate data, and study objective. For example, some studies want to know the nutrient enrichment of a water body for use by phytoplankton or other primary producers rather than meet the environmental quality of coastal body.

Of the nearly 200 estuaries and coastal lagoons (De la Lanza-Espino et al. 2013), only 60 of them have been assessed. The regions most recently served for are the Gulf of California, the Yucatan Peninsula, and the state of Veracruz (Table 12.1). Greater research effort must be applied in all regions of the country with emphasis on estuaries and coastal lagoons where there is a high anthropogenic pressure (agriculture, aquaculture, tourism, and urban activities) and that have never been evaluated.

Notably, most evaluations have been specific and unique, and this has not allowed a complete understanding of the development of eutrophication in Mexico. Long series of data to better understand the interannual changes and Mexican response to nutrient inputs from anthropogenic sources of coastal systems are necessary.

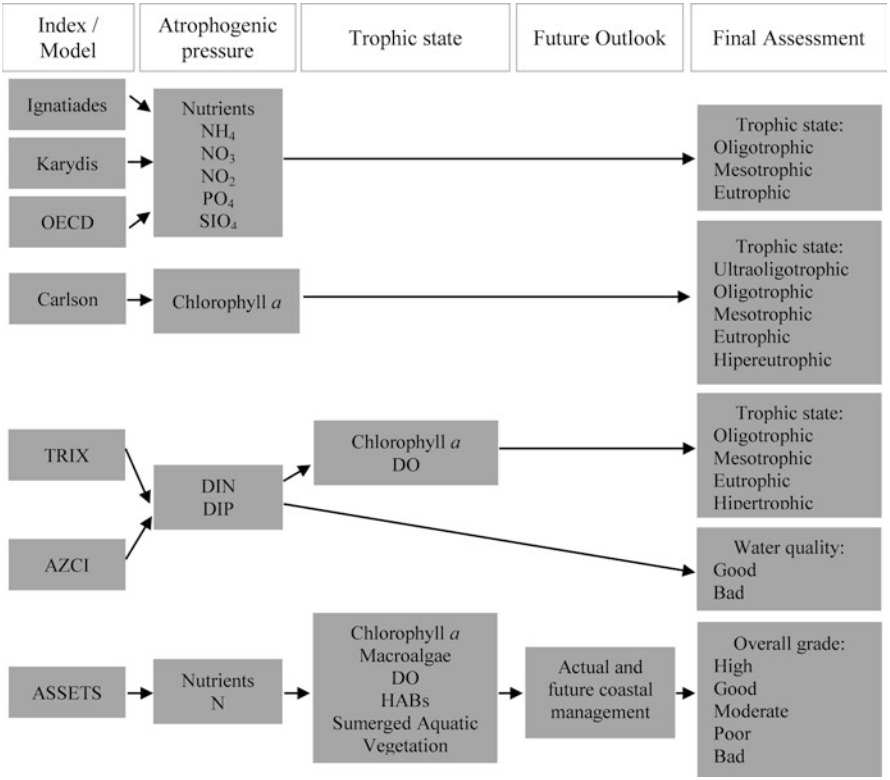

Fig. 12.3 General characteristics and data requirements of coastal eutrophication indices and model used for assessing estuaries and coastal lagoons of Mexico

12.4 Pollution Trace Elements

In geochemistry, the most often used definition of trace element (TE) is as follows: chemical element whose concentration in the Earth's crust is less than 0.1 mass% (Navrátil and Minařík 2005). Here we consider the TE as any element, metallic or not, other than the few major constituents (carbon (C), H, nitrogen (N), sulfur (S), O, phosphorus (P), chlorine (Cl), K, Na, Ca, and Mg) forming most of the living and mineral matter (except Fe and Al). Fe, which is considered a micronutrient because the human body needs it in very small amounts (<100 mg day-1) (Fraga 2005), will also be included in the definition of TE.

Since the industrial revolution, the production of metals such as lead (Pb), copper (Cu), and zinc (Zn) has increased exponentially. Between 1850 and 1990, the production of these three metals and their emissions to the environment increased almost tenfold (Nriagu 1996). The continental runoff and atmospheric deposition are the primary natural inputs of TE in the marine environment (Callender 2003): the shell material is leached (dissolved) and eroded from the surface of the Earth or

Table 12.1 Eutrophication assessment in estuaries and coastal lagoons of Mexico

Estuary/coastal lagoon	State of Mexico	Index/model	Result	References
Bahía Concepción	Baja California Sur	Ignatiades	Eutrophic (PO_4, SiO_4)	López-Cortés et al. (2003)
			Meso-eutrophic (NO_3)	
			Oligotrophic (NO_2)	
		Karydis	Eutrophic (PO_4, SiO_4)	
			Oligotrophic (PO_4, NO_2, NO_3)	
		AZCI	Good water quality	Mendoza-Salgado et al. (2005)
San José	Baja California Sur	AZCI	Good water quality	Morquecho et al. (2012)
Joya-Buenavista	Chiapas	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Buenavista	Chiapas	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Carretas	Chiapas	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Pereyra	Chiapas	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Bobo	Chiapas	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Cerritos	Chiapas	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Chantuto	Chiapas	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Teculapa	Chiapas	Carlson	Mesotrophic	Contreras-Espinosa et al. 1994
Panzacola	Chiapas	Carlson	Mesotrophic	Contreras-Espinosa et al. (1994)
Campón	Chiapas	Carlson	Mesotrophic	Contreras-Espinosa et al. (1994)
Chantuto-Panzacola	Chiapas	Carlson	Mesotrophic	Gómez et al. (2014)
		TRIX	Eutrophic	
Mar Muerto	Chiapas/Oaxaca	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Coyutlán	Colima	OECD	Oligotrophic (nutrients)	Sosa-Avalos et al. (2013)
			Eutrophic (Chl *a*)	
Corralero	Oaxaca	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Chacahua	Oaxaca	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Pastoría	Oaxaca	Carlson	Mesotrophic	Contreras-Espinosa et al. (1994)
Superior e Inferior	Oaxaca	Carlson	Mesotrophic	Contreras-Espinosa et al. (1994)
San José Manialtepec	Oaxaca	–	Eutrophic	Contreras and García-Nagaya (1991)

Sian Ka'an	Quintana Roo	Comparison with near lagoons	Oligo-mesotrophic	Lagomasino et al. (2014)
El Colorado	Sinaloa	AZCI	Bad water quality	Morquecho et al. (2012)
Mazatlán	Sinaloa	Ignatiads	Eutrophic (NH_4, NO_3)	Alonso-Rodríguez et al. (2000)
			Mesotrophic (NO_3, NO_2)	
			Oligotrophic (PO_4, SiO_4)	
		Karydis	Eutrophic (NH_4, NO_3, PO_4, SiO_4)	
			Meso-oligotrophic (NO_2)	
Topolobampo-Ohuira-Santa María	Sinaloa	TRIX	Eutrophic	Ayala-Rodríguez (2008)
				Escobedo-Urías (2010)
Santa María – La Reforma	Sinaloa	ASSETS	Poor condition	Arreola-Lizárraga et al. (2009)
Altata-Pabellón	Sinaloa	ASSETS	Bad condition	Arreola-Lizárraga et al. (2009)
San Ignacio-Navachiste-Macapule	Sinaloa	TRIX	Eutrophic	Escobedo-Urias (2010)
Macapule	Sinaloa	Ignatiades	Eutrophic (PO_4, NO_3, NH_4)	Magaña-Álvarez (2004)
		Carlson	Oligotrophic	
Guásimas	Sonora	ICAC	Good water quality oligotrophic	Reynaga-Franco (2009)
		TRIX		
Algodones	Sonora	ICAC	Good water quality oligotrophic	Reynaga-Franco (2009)
		TRIX		
Guaymas	Sonora	TRIX	Mesotrophic (with wastewater) oligotrophic (without wastewater)	Elizalde-Servín (2009)
		ASSETS	Good condition	
		TRIX	Mesotrophic	Ruiz-Ruiz et al. (2016)
		AZCI	Good water quality	Ruiz-Ruiz (2017)
Empalme-El Rancho	Sonora	ICAC	Good water quality oligotrophic	Reynaga-Franco (2009)
		TRIX		
		TRIX	Mesotrophic (winter) and oligotrophic (rest of year)	Medina-Galván (2010)
		TRIX	Oligo-mesotrophic	Arreola-Lizárraga et al. 2016

(continued)

Table 12.1 (continued)

Estuary/coastal lagoon	State of Mexico	Index/model	Result	References
Yavaros	Sonora	ASSETS	Poor condition	Arreola-Lizárraga et al. (2009)
		ICAC	Good water quality	Morquecho et al. (2012)
Lobos	Sonora	TRIX	Oligotrophic and mesotrophic (in discharge)	Ruiz-Ruiz et al. (2017)
		AZCI	Good water quality	
		ASSETS	Good condition	
El Tóbari	Sonora	TRIX	Mesotrophic	Ruiz-Ruiz (2017)
		AZCI	Bad water quality trend	
		ASSETS	Moderate condition	
El Soldado	Sonora	TRIX	Oligotrophic	Ruiz-Ruiz (2017)
		AZCI	Good water quality	
El Carmen	Tabasco	Carlson	Mesotrophic	Contreras-Espinosa et al. (1994)
Machona	Tabasco	Carlson	Mesotrophic	Contreras-Espinosa et al. (1994)
Mecoacán	Tabasco	Carlson	Mesotrophic	Contreras-Espinosa et al. (1994)
Madre	Tamaulipas	Carlson	Mesotrophic	Contreras-Espinosa et al. (1994)
Carpintero	Tamaulipas	Carlson	Eutrophic	Crisóstomo-Vázquez et al. (2016)
Pueblo viejo	Veracruz	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Tamiahua	Veracruz	Carlson	Mesotrophic	Contreras-Espinosa et al. (1994)
Tampamachoco	Veracruz	Carlson	Mesotrophic and eutrophic	Contreras-Espinosa et al. (1994)
		TRIX	Mesotrophic	Rivera-Guzmán et al. (2014)
Tuxpan	Veracruz	Carlson	Mesotrophic	Contreras-Espinosa et al. (1994)
La Mancha	Veracruz	Carlson	Mesotrophic	Contreras-Espinosa et al. (1994)
		–	Eutrophic	Varona-Cordero et al. (2014)
		TRIX	Mesotrophic and eutrophic	Rivera-Guzmán et al. (2014)
Mandinga	Veracruz	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Camaronera	Veracruz	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Alvarado	Veracruz	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
		TRIX	Eutrophic and mesotrophic	Rivera-Guzmán et al. (2014)

Tlalixcoyan	Veracruz	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Sontecomapan	Veracruz	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
Rio Calzadas	Veracruz	Carlson	Eutrophic	Contreras-Espinosa et al. (1994)
El Ostión	Veracruz	Carlson	Mesotrophic	Contreras-Espinosa et al. 1994
Casitas	Veracruz	TRIX	Eutrophic	Rivera-Guzmán et al. (2014)
Grande y Chica	Veracruz	TRIX	Eutrophic	Rivera-Guzmán et al. 2014
Progreso	Yucatán	ASSETS	Poor condition	Herrera-Silveira and Morales-Ojeda (2009)
		Karydis	Oligo-mesotrophic	Herrera-Silveira et al. (2004)
Dzilam	Yucatán	ASSETS	Good condition	Herrera-Silveira and Morales-Ojeda (2009)
		Karydis	Oligotrophic	Herrera-Silveira et al. (2004)
		Karydis	Mesotrophic (NH_4, NO_3, PO_4)	Herrera-Silveira et al. (2002)
		Carlson	Meso-eutrophic	
Celestúm	Yucatán	Karydis	Meso-eutrophic (NO_3, PO_4)	Herrera-Silveira et al. (2002)
			Mesotrophic (NH_4)	
		Carlson	Meso-eutrophic	
		Karydis	Oligo-mesotrophic	Herrera-Silveira et al. (2004)
		Karydis	Oligotrophic (NO_2, SRP)	Tapia González et al. (2008)
			Oligo-mesotrophic (NH_4, NO_3)	
			Mesotrophic (SRPSi, Chl a)	
		Carlson	Mesotrophic	Contreras-Espinosa et al. (1994)
Chelem	Yucatán	Karydis	Oligotrophic (NO_3, PO_4)	Herrera-Silveira et al. (2002)
			Mesotrophic (NH_4)	
		Carlson	Oligotrophic	
		Karydis	Oligotrophic (SRP)	Tapia González et al. (2008)
			Oligo-mesotrophic (Chl *a*)	
			Mesotrophic (NO_2, NO_3, NH_4, SRPSi)	
Sisal	Yucatán	Karydis	Mesotrophic	Herrera-Silveira et al. (2004)

introduced into the atmosphere by volcanic activity. Forest fires and biogenic sources are minor (Nriagu 1996). More recently, as a natural source, it has been linked to the influence of seasonal upwelling (e.g., southeast of the Arabian Sea) and ocean currents (e.g., Eastern Pacific) with variability in the concentration of TE between the coastal lagoons (Apeti et al. 2005; Cheriyan et al. 2015). In addition to these natural sources, there is a multitude of sources, resulting from mining and smelting activities (Callender 2003) and anthropogenic emissions. However, the growth of industrial, agricultural, and urban activities since the early 1960s (Richir and Gobert 2016) and recently intensive aquaculture (Cheriyan et al. 2015) have significantly influenced the contribution of TE in coastal areas (Farmaki et al. 2014). Förstner and Wittmann (1979) concluded that among the world's most polluted aquatic environments are TE estuaries and coastal lagoons.

The interaction of both natural and anthropogenic sources, in the solid-liquid interface, is especially important in coastal areas. In them is where the most important changes in the concentration, distribution, and toxicity of TE are to be modified, along with its chemical composition (Du Laing et al. 2009).

Multiple anthropogenic sources affect marine sediments (Delgado et al. 2011) in which sorption processes and sedimentation of TE depend mainly on the size, the grain texture, and the content of organic matter (Fukue et al. 2006; Magesh et al. 2013). Most TEs are linked to the fine fractions of the sediment (<63 μm) due mainly to surface area ratio of the grain size on the content of humic substances which presents an increased bioavailability potential depending on the metal oxidation state and extent of absorption (Sharma and Singh 2015; Tercierwaeber and Taillefert 2008).

Zhang et al. (2014) indicate that the major factors influencing the bioavailability and toxicity of TE in sediments and water column are (1) solid phases, especially TE-bound acid-volatile sulfides, particulate organic carbon, iron oxyhydroxides, and Mn; (2) water phase, i.e., overlying porous, water physicochemical attributes such as pH, redox potential (Eh), hardness, salinity, and ligand complexes; and (3) biological benthic organisms that are exposed to TE present in the system, including previous exposure characteristics.

In this chapter, a compilation of contributions containing information on TE concentrations in sediments of estuaries and coastal lagoons of Mexico (Table 12.2) is presented. This was done considering that the sediment can store up to 100,000 times more TE than surface water (Förstner and Wittmann 1979). In addition, sediment concentration of TE defines the extent of human influence and potential ecotoxicological risk by identifying the pristine condition (Birch and Olmos 2008; Fukue et al. 2006).

A number of indices have been developed to assess the level of contamination of trace elements in sediments (Caeiro et al. 2005). These include the metal pollution index (MPI) (Usero et al. 1997), the enrichment factor (EF) (Tang et al. 2010), and the geoaccumulation index (Igeo) (Muller 1979; Lin et al. 2011). These indices allow to obtain the necessary information to know whether there is an enrichment or reduction of the metal element. In this regard, sediment quality will depend largely on the content of trace elements; the variability in these elements can be linked to

Table 12.2 Intervals or averages of the total concentration of metals in surface sediments from various coastal lagoons of Mexico (followed by a standard deviation when the data was available)

State/site	Ag	Al	Cd	Co	Cr	Cu	Fe	Hg	Li	Mn	Ni	Pb	V	Zn	References
Pacific Coast															
Baja California															
Baja California border–California	0.01–0.2	3.6–8.6	0.1–0.6		56–802	4.9–23	1.4–4.6			392–1506	16–44	6–21		39–188	Villaescusa-Celaya et al. (2000)[a]
Bahía Todos Santos			10.0		ND-150	10–100					20–60			20–140	Rosales-Hoz et al. (1994)[b]
Laguna San Quintín			0.1–1.8		19.9–92.2	1.8–20.5					25.1–105			8.6–107	Gutiérrez-Galindo et al. (2007)[a]
Laguna San Quintín				25.0 ± 17.2	31.6 ± 12.5		3.5 ± 1.1								Daesslé et al. (2009)[a]
Baja California Sur															
Laguna de Guerrero Negro			0.2	3.4	21.7	2.5	1.2				4.5			21.4	Choumiline et al. (2000)[a]
Laguna Ojo de Liebre			0.1	3.1	23	3.5	1.2				6.7			22.3	Choumiline et al. (2000)[a]
Bahía Concepción			13 ± 35	27 ± 89	106±70	31±31	4.0±2.0				69±146	92±256		54±33	Rodríguez-Meza (2004)
BahíasMagdalena–Almejas			3±3	6±7	102±271	5±9	1.5±1.4				20±33	6±12		10±17	Rodríguez-Meza (2004)
Laguna De La Paz				5±3	22±15		2±1	0.02±0.01			48±35			34±25	Rodríguez-Meza (1999)
Laguna De La Paz		7.0 ± 2.7	3.5 ± 0.9	36.9±10.1	33.2±28.3	9.1±6.9	1.4±0.9		4.6±3.1	178±98	27.1±6.2	52.7±15.7		44.7±26.1	Green-Ruiz (2000)
Formación San Gregorio			14	12	335	16				67	28			93	Álvarez-Arellano and Páez-Osuna (1995)

(continued)

Table 12.2 (continued)

State/site	Ag	Al	Cd	Co	Cr	Cu	Fe	Hg	Li	Mn	Ni	Pb	V	Zn	References
Sonora															
Delta del Río Colorado				0.09 ± 0.03	0.5 ± 0.2		300 ± 110				2.0 ± 2.0			0.6 ± 0.3	Shumilin et al. (2002) (mmol kg^{-1})
Alto Golfo de California				0.09 ± 0.04	0.5 ± 0.3		310 ± 145				0.8 ± 0.8			0.7 ± 0.4	Shumilin et al. (2002) (mmol kg^{-1})
Bahía Bacochibampo		0.7–1.4	0.7–1.3		3.1–17.7	2.2–9.7	0.6–4.4			125–925		7.2–11.7			Ochoa-Valenzuela et al. (2009)[a]
Guaymas		7.0 ± 1.4	4.1 ± 0.9	38.9 ± 5.7	32.3 ± 12.0	52.7 ± 50.1	2.3 ± 0.9		8.5 ± 3.6	257 ± 83	40.8 ± 9.5	66.2 ± 34.1		163 ± 136	Green-Ruiz (2000)[a]
El Soldado			0.92–2.48			0.34–20.2	0.24–2.29			21.3–211	7.2–37.5	2.98–16.5		9.7–70	Vargas-González et al. (2017)
Lobos			0.22–2.39			3.3–25.8	1.70–3.64			133–889	3.3–98.3	4.16.32.2		41.3–118	Vargas-González et al. (2017)
Tobari			ND-2.81			0.50–22.3	0.71–4.34			217–1424	ND-20.6	ND-29.1		15.2–85	Vargas-González et al. (2017)
Sinaloa															
Bahías de Ohuira y Topolobampo		4.9 ± 1.7	2.8 ± 0.8	39.7 ± 10.0	29.9 ± 11.9	8.5 ± 3.8	1.9±0.7		8.9±3.5	506±267	35.6±8.0	53.1±11.2		61.6±20.8	Green-Ruiz (2000)[b]
Altata-Ensenada del Pabellón	3.8 ± 1.1	4.6 ± 2.1	0.5 ± 0.4	17.4 ± 5.5	15.7 ± 3.9	29.3 ± 15.5	5.4 ± 2.2		19.1 ± 9.6	925 ± 1127	14.7 ± 8.0	121 ± 56.7	34.6 ± 10.4	80.5± 40.0	Green-Ruiz (1996)[b]
Laguna Ceuta			1.8	12	7	9	1.2			333	10	13		27	Osuna-López (1981)
Pto. de Mazatlán			1.2	15	29	20	2.2				17	30		85	Osuna-López et al. (1986)

Pto. de Mazatlán		6.9 ± 1.9	3.2 ± 0.5	40.3 ± 7.3	31.0 ± 7.2	6.3 ± 3.1	2.6 ± 0.7		7.5 ± 1.9	569 ± 132	23.1 ± 6.6	64.2 ± 17.2		82.2 ± 19.8	Green-Ruiz (2000)[b]
Pto. de Mazatlán			3.1–3.3			31.9–44.9						49.6–54.0		218–324	Jara-Marini et al. (2008)
Estero de Urías	0.5–2.0	0.9–7.8	0.4–1.5	4.7–17.6	7.6–42.5	7.7–90.9	1.4–9.5		6.0–34.2	157.7–678	6.1–30.3	15–130.5	14–100.4	46–347.8	Soto-Jiménez (1998)[a]
El Rastro-Estero Urías		6.4 ± 0.4	2.6 ± 0.5	39.4 ± 3.7	28.6 ± 3.5	29.9 ± 3.8	2.7 ± 0.2		8.1 ± 0.7	374 ± 30	36.6 ± 4.1	63.3 ± 11.2		121 ± 18.8	Green-Ruiz (2000)[b]
Laguna Huizache-Caimanero			0.1–0.9	4.2–9.9		6.4–24.1	0.6–2.3				2.5–9.9	21.7–68.9		35.6–108	Frías-Espericueta et al. (2004)[a]
Jalisco															
Laguna Barra de Navidad		23.5–127	0.05–0.3	6.0–94.5		19.3–96.2	25.7–69.7				8.5–26.1	2.3–17.8		52.3–79.3	Marmolejo-Rodríguez et al. (2007)[a]
Colima															
Estero Potrero Grande				26.2 ± 2.8	30.0 ± 4.3	34.6 ± 9.1	5.8 ± 0.4			145 ± 31.8	158 ± 90	8.0 ± 2.6		103 ± 27	Lara-Villa (2003)[b]
Laguna Las Garzas			ND-0.04		0.08–0.2	0.07–1.9				ND-6.9	0.03–0.2	ND-0.2		ND-3.8	Bejarano-Ramirez et al. (2017)[a]
Puerto de Manzanillo			ND-0.04		0.03–0.3	0.05–2.2				ND-4.0	0.03–0.2	ND-0.7		ND-4.1	Bejarano-Ramirez et al. (2017)[a]
Guerrero															
ca. Tecpan de Galeana			0.09–0.4			47.6–68.7		0.03–0.08				6.9–13.0	119–208		Chiprés et al. (2009)[a]
Laguna Mitla		5.5		13	121	55	4.1			769	44	9		103	Páez-Osuna and Osuna-López (1987)
Laguna Chautengo			1.1–3.1	16–38	20–81	14–46	2.0–8.3			315–1063	23–70			41–135	Páez-Osuna et al. (1984)[b]

(continued)

Table 12.2 (continued)

State/site	Ag	Al	Cd	Co	Cr	Cu	Fe	Hg	Li	Mn	Ni	Pb	V	Zn	References
Oaxaca															
Salina Cruz, Puerto					20–88						11–99	7–85			Pica-Granados et al. (1994)
Salina Cruz, Puerto-Muelle			2.4–3.3		21.0–36.1	13–136		0.02–2.18			16.8–24.9	42–124		58–423	González-Lozano et al. (2010)[a]
Salina Cruz, zona litoral			0.5–2.3		8.6–79.4	3.7–15.5		0.02–0.11			8.7–24.9	13–38		0.4–351	González-Lozano et al. (2010)[a]
Estuario La Ventosa			4.4–4.9		27.8–54.4	9.3–22.2		0.05–0.20			23.6–39.9	36–63		81–104	González-Lozano et al. (2010)[a]
Chiapas															
Laguna Carretas-Pereyra			1.3 ± 0.5			38.6 ± 12.4						52.9 ± 7.6		74.4 ± 15.6	Villanueva and Botello (1998)[a]
Laguna Chatuto-Panzacola			1.4 ± 0.6			39.9 ± 9.0						54.0 ± 11.5		70.1 ± 21.0	Villanueva and Botello (1998)[a]
Gulf of Mexico and Caribbean Coasts															
Tamaulipas															
Laguna Madre			0.04 ± 0.01			1.6 ± 0.2	1600 ± 325			22 ± 5	3.0 ± 0.3			4.0 ± 0.3	Pulich (1980)[a]
Laguna San Andrés			0.11–1.95	2.07–6.62		0.58–18.6	75–2770			60–1820	2.31–10.0	6.59–21.6		1.48–16.6	Vázquez et al. (1994)[a]
Laguna San Andrés						17.5 ± 11.6					9.5 ± 5.8	5.7 ± 5.0			García-Navarro (2006)[a]

Marismas de Altamira						36.1 ± 42.7					17.5 ± 4.4	18.7 ± 24.1			García-Navarro (2006)[a]
Veracruz															
Laguna de Pueblo Viejo						28.5 ± 20.6					28.4 ± 15.8	24.1 ± 13.6			García-Navarro (2006)[a]
Laguna Tampamachoco			0.1 ± 0.1		9.6 ± 4.2			0.01 ± 0.05				3.9 ± 3.0			Rosas et al. (1983)[a]
Laguna Llano			1.4 ± 0.5	25.9 ± 8.1	36.2 ± 13.8	71.0 ± 17.6					49.7 ± 23.6	78.8 ± 24		87.0 ± 17.2	Rodríguez (1994)[a]
Laguna La Mancha			1.5 ± 0.5	27.7 ± 11.2	49.8 ± 16.6	60.8 ± 20.7					61.4 ± 15.3	81.2 ± 11.1		92.1 ± 15.1	Rodríguez (1994)[a]
Laguna Mandinga			0.02 ± 0.03		7.4 ± 8.3			0.03 ± 0.01				3.3 ± 3.2			Rosas et al. (1983)[a]
Laguna Mandinga			1.1 ± 0.6	31.1 ± 6.2	21.9 ± 10.1	29.8 ± 23.3					26.3 ± 8.0	55.2 ± 24.4		4.8 ± 4.7	Hernández et al. (1996)[a]
Laguna Salada			2.2 ± 0.9	32.4 ± 12.2	29.7 ± 7.8	52.3 ± 24.5					37.7 ± 20.6	77.2 ± 21.8		108 ± 25.2	Rodríguez (1994)[a]
Laguna de Alvarado		1.83–8.8		ND-47.9	ND-626.6	ND-32.6	0.1–10.6			108–1710	ND-143.7	ND-39.5		5.0–169.1	Rosales-Hoz et al. (1986a)[a]
Laguna de Alvarado		3.8–9.9	ND-1.9	18.6–31.6	60.3–96.6	9.7–50	2.8–6.5			630–1595	16.9–41.1	13.7–48.8		63.6–158	Álvarez et al. (1986)
Laguna Papaloapan		1.3–13.8		ND-22.8	30.6–124	13.7–32.2	0.8–3.0			167–1182	23.2–87.3	ND-38.5		6.6–88.8	Rosales-Hoz et al. (1986b)[a]
Laguna Sontecomapan			ND-2.7	ND-51.2	15–150.6	ND-131.4					ND-269.6	ND-48.0		ND-104.4	González-Fierro et al. (1994)
Laguna Sontecomapan			ND-1.7	14–35	70–86	22–40					74–125	12–34		42–66	Ponce et al. (1994)

(continued)

Table 12.2 (continued)

State/site	Ag	Al	Cd	Co	Cr	Cu	Fe	Hg	Li	Mn	Ni	Pb	V	Zn	References
Laguna Ostión			ND	35.8±16.8	141±80.2	39.9±26.7					50.7±18.6	ND		62.1±21.7	Páez-Osuna et al. (1986)[a]
Río Coatzacoalcos (Estuario)			1.6±0.6	21.6±5.6	71.8±28.8	25.7±12.5					34.8±13.2	43.4±17.3		85.7±37.5	Páez-Osuna et al. (1986)[a]
Tabasco															
Laguna del Carmen			0.3 ± 0.2		30.5 ± 28.6			0.01 ± 0.00				6.5 ± 5.2			Rosas et al. (1983)[a]
Campeche															
Laguna Atasta			0.02 ± 0.01		1.0 ± 1.2			<0.007				0.3 ± 0.2			Rosas et al. (1983)[a]
Laguna de Términos			1.4±0.4	12.3±4.7	47.2±29.9	7.4±3.5					50.9±40.3	34.0±18.2		20.4±16.0	Ponce (1988)[a]
Laguna de Términos				1.8±1.8			806±1162			47.4±55.5	20.1±14.2	0.7±1.2	ND	11.6±8.0	Canedo-López et al. (2014)
Yucatán															
Costa poniente			1.7–2.9		3.2–6.9	1.2–2.5						10.9–28.5			Medina-González et al. (2004)[a]
Costa central			1.8–2.8		3.4–5.2	0.8–2.4						2.5–26.1			Medina-González et al. (2004)[a]
Costa oriental			1.8–2.8		3.5–6.4	1.1–2.5						17.0–27.1			Medina-González et al. (2004)[a]
Laguna Chelem		0.9–1.5			ND-41.6	1.2–24.1	1.3–2.0			9.5–43.1	7.1–14.3	0.1–13.5		25.3–41.6	Arcega-Cabrera et al. (2015)[a]

Quintana Roo															
Laguna Bojórquez			ND	ND	ND	36.3					87.3	ND		57.2	De León and Peña (1987) cited in Villanueva and Botello (1992)[a]
Laguna de Nichupté			ND		ND							ND			De León and Peña (1987) cited in Villanueva and Botello (1992)[a]
Bahía Chetumal			1.5 ± 0.1			4.8 ± 0.4	847 ± 26.6				27.6 ± 0.3	23.4 ± 0.7	105 ± 49.3	5.9 ± 0.4	García-Ríos and Gold-Bouchot (2002)[a]
Bahía Chetumal			0.01–1.0					0.04–2.25				0.17–5.6		28.7–277	Díaz-López et al. (2006)[a]

ND Not detected
[a]Values in mg/Kg, except Al and Fe (%)
[b]Values in ppm, except Al and Fe (%)

the magnitude of the anthropogenic influence and the potential loss of health of estuaries and coastal lagoons, as well as their involvement in the flora and fauna.

Considering the diversity of estuaries and coastal lagoons in Mexico, an analysis at the level of regions containing a spectrum of pristine vs contaminated lagoons can provide valuable information on the condition and environmental trend of gaps in the country. For example, Vargas-González et al. (2017) compared the quality of the surface sediments of Lobos and Tóbari coastal lagoons (recipients of agricultural and urban wastewater) with the pristine lagoon El Soldado in the Gulf of California. Concentrations of nickel, zinc, copper, cadmium, manganese, lead, and iron were determined in sediments of these gaps, and metal contamination index (ICM), enrichment factor (EF), and geoaccumulation index (Igeo) were applied. Both the Lobos lagoon and the Tóbari, manganese was the only element submitted a EF indicating Igeo human influence and corresponding to moderate. Sediment quality guideline values suggest that at sites with nickel concentrations >51.6 μg/g (a site in Lobos) and manganese >260 μg/g (Lobos and Tóbari), mitigation measures must be established, because at these levels, these elements may cause adverse effects and deterioration of habitat that species used for breeding, rearing, and/or protection in these coastal ecosystems.

12.5 Estuaries and Coastal Lagoons in Protected Areas

In Mexico, the National Commission of Protected Natural Areas (CONANP) administers 182 federal areas that account for 90,839,522 ha, which include Biosphere Reserve (BR), National Park (NP), Natural Monument (NM), Sanctuary (SC), Area of Natural Resources Protection (ANRP), and Floristic and Faunistic Protected Area (AFFP) (CONANP 2017). All these categories of PNA may include coastal and marine ecosystems and be considered as Marine Protected Areas (MPA) "a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Day et al. 2012).

Estuaries and coastal lagoons are valuable and sensitive environments. Based on information from the National Commission of Protected Natural Areas on coastal environments in Mexico it was observed that 23 coastal lagoons and estuaries are a part of NPAs, of which 16 are Biosphere Reserves (sites with various ecosystems and which promote sustainable development of local communities), 5 are Floristic and Faunistic Protected Area (sites to protect where species of particular interest live, develop, and evolve), and 2 are National Parks (sites with ecosystems that mostly have scenic beauty and have aptitude for tourism development) (Table 12.3).

This seems a small number, but in this set of PNA, larger coastal lagoons in Mexico (Laguna Madre, Laguna de Términos, Laguna de la Ascención, Sistemas Lagunares de Marismas Nacionales) and from differents regions of the country are represented (Fig. 12.4).

Table 12.3 Estuaries and coastal lagoons within protected areas in Mexico

Number	Coastal lagoon or estuary	Area (ha)	Protected area	Protected area category	Area (ha)	Decree year
1	Laguna Guerrero Negro	2,100	El Vizcaíno	Biosphere Reserve	2,546,790	1988
2	Laguna San Ignacio	17,500	El Vizcaíno	Biosphere Reserve	2,546,790	1988
3	Laguna Ojo de Liebre	36,600	El Vizcaíno	Biosphere Reserve	2,546,790	1988
4	Laguna Manuela	600	Valle de los Cirios	Floristic and Faunistic Protected Area	2,521,988	1980
5	Estuario del Rio Colorado	10,470	Alto Golfo de California y Delta del Río Colorado	Biosphere Reserve	934,756	1993
6	Humedales Bahía Adair	42,430	Alto Golfo de California y Delta del Río Colorado	Biosphere Reserve	934,756	1993
7	Laguna de Agua Brava	85,387	Marismas Nacionales	Biosphere Reserve	133,854	2010
8	Teacapan-Agua Grande	39,585	Marismas Nacionales	Biosphere Reserve	133,854	2010
9	Laguna grande-Chametla	10,635	Marismas Nacionales	Biosphere Reserve	133,854	2010
10	Lagunas de Chacahua	1,100	Lagunas de Chacahua	National Park	14,896	1937
11	Laguna de Pastoría	2,300	Lagunas de Chacahua	National Park	14,896	1937
12	Carretas-Pereyra	3,690	La Encrucijada	Biosphere Reserve	144,868	1995
13	Chantuto-Panzacola	3,160	La Encrucijada	Biosphere Reserve	144,868	1995
14	Laguna Madre	200,000	Laguna Madre y Delta del Río Bravo	Floristic and Faunistic Protected Area	572,808	2005
15	Laguna Sontecomapan	891	Los Tuxtlas	Biosphere Reserve	155,122	1998
16	Laguna de Términos	170,000	Laguna de Téminos	Floristic and Faunistic Protected Area	706,148	1994
17	Laguna La Carbonera	1,650	Los Petenes	Biosphere Reserve	282,858	1999
18	Laguna Celestun	2,800	Ría Celestum	Biosphere Reserve	81,482	2000
19	Estero Lagartos	9,100	Río Lagartos	Biosphere Reserve	60,347	1999

(continued)

Table 12.3 (continued)

Number	Coastal lagoon or estuary	Area (ha)	Protected area	Protected area category	Area (ha)	Decree year
20	Laguna Yalahau	27,500	Yum Balam	Floristic and Faunistic Protected Area	154,052	1994
21	Laguna Nichupté	11,000	Manglares de Nichupté	Floristic and Faunistic Protected Area	4,357	2008
22	Laguna Campechén	1,378	Sian Ka'an	Biosphere Reserve	528,148	1986
23	Bahía de la Ascención	74,000	Sian Ka'an	Biosphere Reserve	528,148	1986

Fig. 12.4 Map of Mexico showing the categories of Protected Natural Areas that include estuaries and coastal lagoons

Notably, due to the geographical location of Mexico comprising tropical and subtropical latitudes, the predominant vegetation associated with coastal estuaries and coastal lagoons consists of mangroves. In fact, the country ranks fifth worldwide for its coverage of mangroves (775,500 ha) representing ~5% of the total coverage (Valderrama-Landeros et al. 2017).

The importance of estuaries and coastal lagoons has been widely recognized internationally, in particular within the framework of the Convention on Wetlands (Ramsar, Iran, 1971) – the so-called Ramsar Convention – and the Convention on Biological Diversity (CBD) signed at the UN Conference on Environment and Development (UNCED) (Rio de Janeiro, Brazil, 1992). The mission of the Convention is the conservation and wise use of wetlands through local and national

Fig. 12.5 Map of Mexico showing the Ramsar sites that include estuaries and coastal lagoons

actions and international cooperation, as a contribution toward achieving sustainable development worldwide.

In this review it was reported that 142 estuaries and coastal lagoons have been designated as Ramsar sites (Fig. 12.5); some of these sites are part of protected areas in Mexico. The country ranks second worldwide for the number of sites. Ramsar coastal wetland sites have an area of 8,643,579 ha. Detailed information can be found at https://www.ramsar.org/es/humedal/mexico.

12.6 Challenges for Science, Management, and Conservation

Management of coastal lagoons and estuaries is associated with three paradoxes: (1) most of the world's cities are located adjacent to these ecosystems, and yet for most of the inhabitants of these cities, these ecosystems represent the major habitats of the natural wildlife they encounter; (2) most of the major coastal lagoons and estuaries in the world have some degree of modification or pollution, yet in many countries there are more and estuarine lagoon systems like other coastal ecosystems are protected natural areas; and (3) many coastal lagoons and estuaries receive pollutants from wastewater and yet are among the most productive coastal ecosystems (McLusky and Elliot 2004).

In Mexico, the coastal area is characterized by the formation of different scenarios reflected in a broad spectrum of coastal water bodies, also including a range of environmental conditions from pristine to eutrophication problems and pollution that reflect these three paradoxes.

The diversity of estuarine and exposed coastal lagoons is explained by the influence of different climatic regions, geologic origins, tide conditions, precipitation rates, rates of evaporation, wind patterns, and coastal water bodies. Camacho-Ibar and Rivera-Monroy (2014) put into context this diversity of factors influencing the processes and vulnerability associated with estuaries and coastal lagoons of Mexico and synthesize case studies, indicating that gaps in different regions have different responses to eutrophication processes, because the dynamics of nitrogen operates differently in a subtropical lagoon than a temperate estuary.

On this, regionalization and classification of coastal lagoons for their geological origin proposed by Lankford (1977) and the classification of lagoons for their geomorphology involving different rates of water exchange with the ocean proposed by Kjerfve (1994) are useful for their ecosystem approach and its application in process management. For example, a comparative analysis of different types of coastal lagoons under different nutrient inputs, observing their responses by the behavior of trophic status of nutrient fluxes, net metabolism, and dilution capacity of contaminants, is a comprehensive approach and useful for understanding ecosystem processes that can be applied to decision-making in environmental management.

It is recognized that the structure and functions of these highly resilient and productive ecosystems, along with their efficient trophic transfer, offer unique opportunities to create enabling environments that can sustain human activities (Cataudella et al. 2015), but also anthropogenic pressures are causal factor of problems of environmental degradation of estuaries and coastal lagoons (eutrophication, pollution by trace elements, other toxic pollutants) involving impacts on productive activities and public health; it is therefore essential to effectively design and implement management policies. For this it is important to consider that factor leading to the general sucess a from estuarine management programs have been summarized as: having key individuals of, a lead agency, an institutional structure, long-term scientific data, widespread public perception of the problem, and an ecosystem level perspective (Boesch 2002).

Conservation and rehabilitation of coastal lagoons and estuaries and biodiversity should be a national priority. Therefore, effective implementation of management in protected areas and Ramsar sites already established by decree is a key issue.

Also with the review and analysis of the processes (migration of sand barriers, rates of water removal, sedimentation rates) and physical properties (temperature, salinity, pH, dissolved oxygen, turbidity) of coastal lagoons in relation to climate change factors (increased mean sea level, temperature increase of the air and sea surface, increased carbon dioxide, extreme rainfall events, hurricane intensity) (Anthony et al. 2009), it is important and necessary to establish adaptation strategies.

The diversity of estuaries and coastal lagoons represents opportunities and challenges for research and management (even from quantification and classification). Opportunities arise to generate scientific knowledge by comparing structure, functions, and processes among a set of these systems in order to establish differences and similarities to transfer that knowledge to use. The challenges are to integrate and systematize the knowledge gained as well as an agenda of long-term research to help better decision-making. In this regard, it is important to consider establishing a national program for estuaries and coastal lagoons that allows for an agenda of research, monitoring, and management of all regions of the country and where the coastal lagoons that are already part of Protected Natural Areas can be part of this selection.

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Chapter 13
Status of the Phylogeography, Taxonomy and Conservation of the Reptiles of the Gulf of California Islands

María Carmen Blázquez, Patricia Vázquez, and Alfredo Ortega-Rubio

Abstract There are more than 90 species of reptiles on the islands of the Gulf of California, and almost half of that number are endemic to the islands. The origin and phylogeography of the species are diverse, and their taxonomy has been changing continuously, especially because of the development of new genetic and genomic techniques.

In this chapter, we summarize the current taxonomy and distribution of the lizards and snakes on the islands. We also summarize the Mexican legislation and regulations to protect them and the management of the natural protected areas that include all the islands.

The insular herpetofauna is well adapted to the climatic and biotic conditions of the islands; it has been evolving there, in isolation, for a very long time; and it is very fragile and unique. The reptiles face several threats including the introduction of exotic species and the illegal collecting. Some islands are also exposed to an increasing rate of tourism (ecotourism), and it is urgent to evaluate the effects of all these factors on the herpetological communities, in order to preserve this rich patrimony of biodiversity.

Keywords Biodiversity · Biogeography · Insular fauna · Mexico

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13.1 Reptile Species on the Islands of Gulf of California

In the Gulf of California, there are 45 major islands (of more than 1 km^2) and about 245 in total, including some very small ones which are barely more than rocks. The islands of the Gulf of California are not homogeneous in age, geology, distance to the coast (Mainland Mexico or Baja California Peninsula) or origin. Very detailed descriptions of their biotic and abiotic characteristics are in Case et al. (2002) as well as a checklist of plants and marine and terrestrial animals, including reptiles.

Despite the fact that the islands are dispersed over a length of about 1600 km, their climatic characteristics follow a common pattern. The climate is generally very arid, with summer rains from the East Pacific hurricanes, little or no winter precipitation, hot summers and mild winters. Because of their small size and low elevation above sea level, the ocean has a regulatory effect, making the daily variation of temperature moderate and seasonally temperate. None of the islands has fresh water. The vegetation is xerophytic and usually structurally poor. In general, the topography is hilly; the slopes of the hills are very exposed to the erosion, the sun and the wind, whilst the valleys, where the water runs after the hurricanes, act as refuges for soil, flora and fauna. The vegetation is thicker on the bottom of the arroyos, and the majority of the terrestrial fauna lives there. The arroyos and the coastal fringe are the most productive part of the islands. The terrestrial fauna, including reptiles, is well adapted to the low, patchy and seasonal productivity, relying also on marine subsidies (Stapp and Polis 2003; Delibes et al. 2015).

Based in Grismer (1999a, 2002), Murphy and Aguirre-León (2002) and Lovich et al. (2009), and reviewing the posterior literature, we registered a highly diverse terrestrial herpetofauna (just reptiles; we are not considering amphibians or marine turtles) of 92 species, distributed in 68 islands: 1 tortoise, 55 lizards and 36 snakes.

13.1.1 Ensemble of Species

The number of species of each island is a combination of its size, its origin and its proximity to the coast, but the species numbers are not maintained at dynamic equilibrium, and instead the turnover rate is low, with less extinction than random (Case 2002; Murphy and Aguirre-León 2002). The richer islands are Tiburon and San Jose with 26 and 22 species, respectively (Grismer 2002). On the other hand, there are many islands with just one species.

Fig. 13.1 *Crotalus catalinensis* from Santa Catalina Island (Author: M.C. Blázquez)

13.1.2 Percentage of Endemicity

The percentage of endemicity for reptiles is 48.4%, one of the highest in the world. Thirty-one taxa (56%) of the lizards and 14 (37%) of the snakes are endemic to one or several islands. The genus *Aspidoscelis* (with 12 species) among the lizards and the genus *Crotalus* (represented by 13 species) among the snakes are the most diverse. The island with the greater percentage of endemics is Santa Catalina (Fig. 13.1). The ten species living there are unique, except for one snake.

13.2 Current Knowledge About Phylogeography, Taxonomy and Conservation

The puzzle of the origin, phylogeography and taxonomy of the reptile species of the islands of the Gulf of California has been intriguing researchers for more than a century, since the first expedition of the boat Albatross, in 1911 (Townsend 1916; Dickerson 1919). There are several reviews of the ensemble of the reptile's species living there (Case 1983, 2002; Grismer 1999a, 2002; Murphy 1983, 1985; Murphy and Aguirre-León 2002; Lovich et al. 2009; Ridlle et al. 2000). The current taxonomy of species and subspecies is in constant revision (Torstrom et al. 2014) specially after generalization of the new genetic and genomic techniques (i.e. Leaché et al. 2015a, b), with scientists trying to match the genetic information with traditional morphology and other considerations as, i.e. local adaptations (Meik et al. 2015).

Because of the difficulty to work accurately at species and subspecies level, about the patterns of distribution of taxa in the peninsula of Baja California, Dolby et al. (2015) proposed the use of evolutionary significant units (ESUs) as a tool. They took the definition of Ryder et al. (1988) and Moritz (1994) and defined an ESU as: a locality where a group of individuals was isolated from other conspecifics for long enough to exhibit meaningful genetic divergence statistically supported by Bayesian assignment tests. They considered that ESUs contribute substantially to the ecological or genetic diversity of a taxon as a whole. They found that the number of ESUs negatively correlated with the ability of individual species to disperse; the reptiles were the group showing the largest average number of ESUs along the peninsula. A similar analysis hasn't been made including the islands yet, but presumably the contribution of the island populations to the total variation of the reptile taxa would be very significant.

Here we summarize the status of the phylogeography and taxonomy of the island species to date.

13.2.1 Tortoises

13.2.1.1 Family Testudinidae

It is represented by one genus and one species.

Gopherus morafkai. Murphy et al. (2011) proposed this name for the Sonoran Desert Tortoise that lives south of the Colorado River, after their revision of the taxonomy of *G. agassizii,* that they found 'engulfed in errors'. This new species comprises two genetically and geographically distinct lineages, and the population of the Tiburon Island belongs to the 'Sonoran' lineage (Edwards et al. 2016). The previous species, *G. agassizii*, was protected by the Mexican law (NOM-059-SEMARNAT 2010), but the new one is not there yet.

13.2.2 Lizards

13.2.2.1 Family Crotaphytidae

It is represented by two genera and three species.

Genus *Crotaphytus*. McGuire et al. (2007) recognized the species *Crotaphytus dickersonae* as endemic to Tiburon Island and the species *C. insularis* as endemic to Angel de la Guarda Island. Despite their endemicity, none of them are in the Mexican list of species at risk or vulnerable (NOM-059-SEMARNAT 2010).

Genus *Gambelia.* One species, *Gambelia wislizenii*, occurs in Tiburon Island. The distributional range of this species is extensive, including Sonora and SW USA, and its status is least concern (http://www.iucnredlist.org/details/64015/0).

13.2.2.2 Family Iguanidae

It is represented by three genera and ten species.

Fig. 13.2 *Dipsosaurus dorsalis* from Carmen Island (Author: M.C. Blázquez)

Fig. 13.3 *Sauromalus varius* from San Esteban Island (Author: MC. Blázquez)

Genus *Ctenosaura*. Its phylogeny was reviewed by Davy et al. (2011). These authors confirmed the separation between C. *hemilopha*, *C. conspiscuosa* and C. *nolascensis* species. Only *C. hemilopha* is considered in the Mexican list of protected species (NOM-059-SEMARNAT 2010), but not the others, despite the fact that they are endemic to San Esteban and San Pedro Nolasco Islands, respectively.

Genus *Dipsosaurus* is represented by two species: *D. catalinensis* that is endemic to Santa Catalina Island and *D. dorsalis* that is present in 11 islands (Fig. 13.2) (Grismer 2002), including one recent population found in El Muerto Island (Lazcano et al. 2011). The phylogeography of this species in the peninsula was studied by Valdivia-Carrillo et al. (2017), but they didn't consider any individual from the islands in their analysis. The Mexican law (NOM-059-SEMARNAT 2010) doesn't protect these two species.

Genus *Sauromalus* is represented by five species in several islands. One of them, *S. klauberi*, is endemic to Santa Catalina Island. A first phylogenetic study about the gigantism in the insular endemic species of this genus was conducted by Petren and Case (1997) and later reviewed by Case (2002). The number of recognized species hasn't changed since; their distribution and current taxonomy is in Grismer (2002),

Fig. 13.4 *Sceloporus grandaevus* from Cerralvo Island (Author: Miguel Delibes)

Velarde et al. (2008) and Lovich et al. (2009). Only two of the endemic species (*S. obesus* = *ater* after 2004, and *S. varius*) (Fig. 13.3) are listed as at risk by the Mexican law (NOM-059-SEMARNAT 2010). The list doesn't include *S. klauberi, hispidus* or *slevini* despite the fact that they are endemic to small islands.

13.2.2.3 Family Phrynosomatidae

It is represented by 6 genera and 23 species.

The phylogeny of the family Phrynosomatidae has been reviewed recently using genomic tools and SNPs markers by Leaché et al. (2015a, b).

Inside the genera, the phylogeography of the species is at different status of knowledge.

Genus *Callisaurus* was studied by Lindell et al. (2005). They concluded that it is just one species, *C. draconoides*, that occurs along the peninsula and in the 13 islands where it can be found. This species is on the list of the threatened species in Mexico (NOM-059-SEMARNAT 2010).

Genus *Petrosaurus* is represented by four species on the islands. One of them is endemic to just two islands (*P. slevini* from Angel de la Guarda and Mejia islands), (other, *P. thalassinus*, is endemic to the peninsula (Aguilars-S et al. 1988). None of them are on the Mexican list NOM-059-SEMARNAT (2010) of species at risk. Only *P. mearnsi*, which has an isolated population living in El Muerto Island, is included in that list. *P. repens* is present in two islands.

Genus *Phrynosoma* is present with one species on the islands: *P. solare* that reaches Tiburon Island, as part of the populations of the Sonoran coast (Grismer 2002; Leaché et al. 2015b). The Mexican law NOM-059-SEMARNAT (2010) doesn't protect this species.

Genus *Sceloporus* is very diverse with more than 90 species grouped in at least 19 groups. Its phylogenomics was revised recently by Leaché et al. (2016); these authors concluded that the maximum diversification of the group started about 20–25 million years ago, maintaining a very dynamic rate and with a constant rate

Fig. 13.5 *Uta palmeri* from San Pedro Martir Island (Author: Christopher Swann)

of extinctions through time. Three groups are present on the islands with eight species (Leaché and Mulcahy 2007; Wiens et al. 2010). The group *clarkii* is represented by *S. clarkii* in Tiburon and San Pedro Nolasco islands; the group *angustus* is represented by two species: *S. angustus* that is endemic to Santa Cruz and San Diego islands and *S. grandaevus* that is endemic to Cerralvo Island (Fig. 13.4). Finally, the group *magister* is represented by five species: among them, *S. lineatulus* is endemic to Santa Catalina Island. The Mexican list of endangered species (NOM-059-SEMARNAT 2010) just includes the *angustu*s group and two species of the *magister* group that also live on the peninsula.

Genus *Urosaurus* is represented by two (or three) species. The group *ornatus* with the species *U. ornatus* is present in Tiburon Island. On the other hand, the taxonomy of group *nigricaudus*, which lives in the peninsula and on 21 islands, is less clear. This group is formed by two species: U. *nigricaudus*, in the southern tip of the Baja peninsula, and *U*. *microscutatu*s, north of the La Paz break in the Baja peninsula (Aguirre et al. 1999; Wiens 1993; Feldman et al. 2011). Lindell et al. (2008) found that the lineages of San Francisco and San Jose islands are older than the La Paz break (which separated the two peninsular species of the group); but they didn't consider that the individuals from these islands were different from those of the peninsula. Therefore, they concluded that all the samples belonged to the same species, *U. nigricaudus*, and dismissed *U. microscutatus* as a different species. Later, Feldman et al. (2011) found the lack of genetic flow between the north and the south of the La Paz break was big enough to split the group again in two species (and recognized *U. microscutatus* again), but they didn't use any samples from the Gulf of California islands. In this last scenario, it is clear the populations of the islands belong to the group *nigricaudus*, but there is no certainty to assign them to one or the other of the peninsular species. *Urosaurus nigricaudus* is protected in NOM-059-SEMARNAT (2010).

Genus *Uta* is represented by seven species on the islands of the Gulf of California; *U. stansburiana* is present in 43 islands (Upton and Murphy 1997; Grismer 2002). The other six species are microendemic, restricted each one to just one island (Grismer 2002). The Mexican law of species at risk (NOM-059-SEMARNAT 2010) includes

Fig. 13.6 *Aspidoscelis celeripes* from San José Island (Author: Miguel Delibes)

three of the microendemic species (*U. nolascensis*, *U. palmeri* (Fig. 13.5) and *U. squamata*) but not the other three, *U. encantadae*, *U. lowei* or *U. tumidarostra*.

13.2.2.4 Family Eublepharidae

It is represented by one genus and two species.

Genus *Coleonyx*. The species *C. gypsicolus* is endemic to San Marcos island (Grismer 2002). It is not protected by the Mexican law (NOM-059-SEMARNAT 2010). The species *C. variegatus* is present in nine islands, and it is protected by the Mexican law NOM-059-SEMARNAT (2010).

13.2.2.5 Family Gekkonidae

It is represented by one genus and five species.

Genus *Phyllodactylus*. Grismer (2002) recognized five species of this genus on the islands of the Gulf of California, all of them are protected by the Mexican law of endemic or vulnerable species (NOM-059-SEMARNAT 2010). Three of these species are endemic to three islands: *P. bugastrolepis* (Santa Catalina Island), *P. homolepidurus* (San Pedro Nolasco Island) and *P. partidus* (Partida Norte Island). The Baja endemic *P. unctus* is present in six islands and *P. xanti* in 32 islands. However, more recently, Blair et al. (2009) analysed the phylogeny of the genus in the peninsula and proposed that the species of the middle of the peninsula is *P. nocticolus* and no *P. xanti* anymore (that they restricted to the southern tip of the peninsula). Unfortunately these authors didn't include any samples from the islands, and it remains unclear the taxonomy of the *Phyllodactylus* of those island populations that originally were *P. xanti* and that now could be *P. nocticolus*, presumably.

13.2.2.6 Family Teiidae

This family is represented by just 1 genus and 12 species.

Genus *Aspidoscelis*. Radtkey et al. (1997) and Reeder et al. (2002) studied the phylogeography of this genus in the Gulf of California islands. The group *hyperythra* is represented by five species (*A. carmenensis*, *A. danheimae*, *A. franciscensis*, *A. hyperythra* and *A. pictus*) and is a sister taxon of *A. ceralbensis*. All of them are microendemic to just one island each species, except *A. hyperythra* that can be found in five islands (Grismer 1999b, 2002).

Five species: *A. bacatus*, *A. canus*, *A. catalinensis*, *A. celeripes* (Fig. 13.6) and *A. martyris* are all endemic to one to three islands; and *A. tigris* lives in 14 islands (Grismer 2002).

All the species of *Aspidoscelis* except *A. carmenensis*, *A. franciscensis* and *A. tigris* are protected in the Mexican law NOM-059-SEMARNAT (2010).

13.2.3 Snakes

The taxonomy and phylogeography of the snakes is less known than that of the lizards. The snakes have a more secretive nature, and therefore there are less specimens in scientific collections, which made less data available to phylogeographic or phylogenetic studies.

13.2.3.1 Family Leptotyphlopidae

It is represented by one genus and one species.

Rena boettgeri. These little burrowing snakes are present in at least seven of the Gulf of California islands. These old snakes are among the poorer known vertebrates in the world. The study of Adalsteisson et al. (2009) showed divergences among living lineages as early as the mid-Cretaceous, 92 (113–75) million years ago, and the authors suggested that there are probably more species that the currently number recognized. However, apart from that study, no other published phylogenetic studies of higher-level relationships exist. The Mexican law NOM-059-SEMARNAT (2010) protects this species.

13.2.3.2 Family Boidae

It is represented by one genus and one species.

Lichanura (=Charina) trivirgata. This species has been found in seven islands of the Gulf of California. Wood et al. (2008) analysing mtDNA proposed a relatively novel phylogeography for this species. First, a northern Gulf vicariance event with ancestral populations distributed in southwestern Arizona extending from there into

Fig. 13.7 *Masticophis flagellum* from San José Island (Author: MC. Blázquez)

the developing Baja California Peninsula, prior to the development of the Gulf of California. Second, a trans-gulf dispersal from west-to-east including a successful mainland invasion in the Sonoran coast. This pattern of migrating west to east has been invoked for only other species, *Phyllodactylus xanti* (Wood et al. 2008). The Mexican law NOM-059-SEMARNAT (2010) protects this species.

13.2.3.3 Family Colubridae

This Family is represented by 13 genera or 12 since 2008, when the genus *Eridiphas* was synonymized with the genus *Hypsiglena* (Mulcahy 2008), and 19 species.

Genus *Bogertophis*. One species, *Bogertophis rosaliae*, that is endemic to the peninsula (Rodríguez-Robles and Escobar 1999) and that has also been found in Danzante and San Marcos islands (Grismer 2002). The Mexican law NOM-059-SEMARNAT (2010) does not protect this species.

Genus *Chilomeniscus* is represented by two species; one of them, *Ch. savagei*, is endemic to Cerralvo Island, and the other, *Ch. stramineus,* is present in seven islands (Grismer et al. 2002). None of them are listed in the Mexican law NOM-059-SEMARNAT (2010).

Genus *Eridiphas* was represented with one species, *E. slevini*, that is endemic to the peninsula of Baja California; it lives on four islands (Mulcahy and Archibald 2003). Mulcahy (2008) synonymized this genus to *Hypsiglena*; as a result, the species *H. slevini* will add the populations of these four islands. The Mexican law NOM-059-SEMARNAT (2010) does not protect this species.

Genus *Hypsiglena* is represented by four species in the Gulf of California islands (Mulcahy 2008; Mulcahy and Macey 2009): *H. gularis* from Partida Norte (Cardonosa) Island, *H. ochrorhyncha venusta* that lives on San Marcos and Danzante islands, *H. chlorophaea catalinae* that is endemic to Santa Catalina Island and *H. slevini* that lives on 17 other islands. The Mexican law NOM-059-SEMARNAT (2010) does not protect this species.

Genus *Lampropeltis*. This genus is represented by two species on the islands (Grismer 2002; Lovich et al. 2009). One of them, *L. catalinensis*, is endemic to Santa Catalina Island. The Mexican law NOM-059-SEMARNAT (2010) does not protect this species, but it does protect the other species, *L. getula*, that is present in 11 islands.

Genus *Masticophis*. Four species of this genus live on the islands. *M. barbouri* is endemic to Espiritu Santo Island, and *M. slevini* is endemic to San Esteban Island (Grismer 2002; Lovich et al. 2009). *M. bilineatus* can be found on Tiburon Island, and the endemic to the peninsula, *M. flagellum*, lives in 12 islands (Grismer 1990, 2002). The Mexican law (NOM-059-SEMARNAT 2010) protects two of the species: *M. barbouri* and *M. flagellum* (Fig. 13.7).

Genus *Phyllorhynchus*. One species, *P. decurtatus*, is present on five islands. The geographic variation in morphology of this genus was revised by Gardner and Mendelsson (2004); they didn't find any discrete difference between taxa (they didn't recognize the subspecies *arenicola* from Montserrat Island), and they concluded that the species lacks consistent geographic pattern classes. A phylogenetic study seems to be necessary to confirm these results. The species is not protected by the Mexican law (NOM-059-SEMARNAT 2010).

Genus *Pituophis*. The phylogeny of this genus was revised by Rodriguez-Robles and De Jesús Escobar (2000), but they didn't include samples from the islands in their analysis. Following their results, the taxa from San José Island could be *P. bimaris*. Nevertheless, later on, Grismer (2002), based in morphological characters, considered it as *P. vertebralis*. Further studies will be necessary to clarify the taxonomy of these taxa, which are endemic to the Baja peninsula and are not protected by the Mexican law (NOM-059-SEMARNAT 2010). On the other hand, the continental taxon *P. catenifer* lives in Tiburon Island (Grismer 2002).

Genus *Rhinocheilus*. It is represented by one species, *R. lecontei.* The morph of Cerralvo Island is considered a subspecies (*R. lecontei etheridge*) based on morphological characters (Manier 2004). A previous phylogenetic study identified *Rhinocheilus* as the sister taxon to all other lampropeltinines (Rodriguez-Robles and De Jesús Escobar 1999), but more genetic analysis within the species of this genus should be necessary to assess the degree of differentiation of the taxa. The Mexican law NOM-059-SEMARNAT (2010) doesn't protect this species.

Genus *Salvadora*. One species, *S. hexalepis*, is present on three islands (Tiburon, San Jose and Espiritu Santo) (Grismer 2002). The taxonomy of this genus hasn't been reviewed since 1945 when Bogert described the morph of Baja California as the subspecies *S. h. klauberi* (in Grismer 2002). The Mexican law NOM-059-SEMARNAT (2010) doesn't protect this species.

Genus *Sonora*. One species, *S. semiannulata*, can be found on San José and San Marcos islands. This is a species that ranges through arid and semi-arid environments in South Central and Western United States and Northern Mexico, including the Baja peninsula (Grismer 2002; Cox and Chippindale 2014), but their phylogeographic pattern in the region hasn't been studied. The status of conservation of the species is of less concern. The Mexican law NOM-059-SEMARNAT (2010) doesn't protect this species.

Fig. 13.8 *Crotalus estebanensis* from San Esteban Island (Author: MC. Blázquez)

Genus *Tantilla*. The species *T. planiceps* had been found on Del Carmen Island (Grismer 2002). In the morphological revision that Wilson and Mata-Silva (2014) made of *Tantilla* species in Mexico, they didn't include any individual from that island. The Mexican law NOM-059-SEMARNAT (2010) doesn't protect this species.

Genus *Trimorphodon*. One species, *T. lyrophanes*, lives on six islands of the Gulf of California (Grismer 2002). The phylogeography of the genus was reviewed by Devitt (2006) and Devitt et al. (2008) who considered the taxa almost endemic to the peninsula. The Mexican law (NOM-059-SEMARNAT 2010) doesn't protect this species.

13.2.3.4 Family Elapidae

It is represented by one genus and one species.

Genus *Micruroides*. One species, *M. euryxanthus*, can be found in Tiburon Island (Grismer 2002). This genus is monospecific, and Slowinsky (1995) considered it as a sister taxon of *Micrurus*. It is the only Elapidae that is adapted to live in desert regions. The Mexican law (NOM-059-SEMARNAT 2010) doesn't protect this species.

13.2.3.5 Family Viperidae

It is represented by 1 genus and 13 species.

Genus *Crotalus*. Thirteen species of rattlesnakes live in the islands of the Gulf of California (Grismer 2002; Murphy et al. 2002; Douglas et al. 2006). Meik et al. (2015) reviewed the phylogeography of the *C. mitchellii* complex, and they didn't recognize *C. muertensis* (Grismer 2002) as a separate species anymore. They did recognize *C. angelensis* as a species endemic to Angel de la Guarda Island and the species *C. pyrrhus* from Cabeza de Caballo, El Piojo and Smith islands. A phylogenetic study of the other complex of the genus (*C. atrox*, *C. molossus*, *C. ruber*) will be necessary to determine and assess the taxonomy of the rest of insular species. *C. catalinensis*, *C. estebanensis* (Fig. 13.8), *C. lorenzoensis* and *C. tortugensis* are endemic to just one island each (Grismer 2002). Tiburon Island has four species of *Crotalus* living there (*C. cerastes*, *C. atrox*, *C. molossus* and *C. tigris*). The Baja endemic *C. enyo* lives on nine islands of the gulf. *C. ruber* lives on seven and *C. mitchellii* on another seven islands. *C. atrox* has been found on four islands. A recent biogeographical study of the genus in Mexico (Hernández-Salinas et al. 2017) didn't include the islands of the Gulf of California. The Mexican law NOM-059-SEMARNAT (2010) protects all the *Crotalus* species of the islands except for *C. angelensis*, *C. estebanensis* and *C. lorenzoensis*.

13.3 Threats to the Herpetofauna of the Islands

13.3.1 Introduced Species

Except for Tiburon Island, the islands have no permanent human population; nevertheless, temporary fishermen or tourist camps may be established for several months in one location. This situation poses the augmented risk of the introduced species coming with the equipment and the food. The confirmed introduced animals on the islands, so far, are domestic cats, domestic mice (*Mus musculus*), black rats (*Rattus rattus*), bighorn sheep (*Ovis canadiensis*) and domestic goats (*Capra hircus*). We don't have information about the house gecko *Hemidactylus frenatus* that is very common in the villages on the peninsula. The invasive species are spread out on several islands, in some cases in critical numbers as, for example, the goats and cats in Cerralvo Island. Bighorn sheep are hunted in Del Carmen Island. Fortunately, there have been some successful eradications of mice, rats and goats; Aguirre-Muñoz et al. (2008) reported the success eradication in the past 10 years of domestic cats from eight islands, rats from six, house mice from Rasa Island and goats from San Francisco Island. The process of eradication of goats and cats is currently in process in Espiritu Santo Island. One of the main difficulties in detecting the invaders is the lack of permanent or regular surveillance in the majority of the islands.

13.3.2 Illegal Collecting

Because the islands are remote and inhabited, it is relatively easy to visit them, unnoticed by any authority or park ranger. It is also very easy to pretend to be a biologist to avoid any suspicions. By doing that, poachers take specimens of unique species, for pets and other activities. Geckos and rattlesnakes are especially vulnerable to this illegal trade. Delibes et al. (2015) suggested that collection of endemic rare taxa for scientific purpose could have been very intense in some of the islands too.

13.4 Mexican Laws to Protect the Biodiversity

There are several Mexican laws to protect the biodiversity of the country; a detailed list can be consulted at pp. 69 of the National Strategy for Mexican Biodiversity 2016–2030 (CONABIO 2016). Four of these laws are relevant for the reptiles inhabiting the islands of the Gulf of California: the most important is the General Law of the Ecological Equilibrium and Environmental Protection (reformed in May 2016), which includes the list of the species considered at risk, threatened or vulnerable in Mexico (NOM-059-SEMARNAT 2010), http://dof.gob.mx/nota_detalle.php?codigo=5173091&fecha=30/12/2010.

Unfortunately, this list is not completely up to date. It includes just 28 species of lizards and 15 snake species of the total taxa of the islands, and not all the endemics are included, as we note in the review above.

Other significant laws are: the General Law of Wildlife (also reformed in May 2016), the General Law of National Goods (reformed in June 2016) and the Federal Law of Environmental Responsibility since June 2013.

Recently they designed the National Strategy about Invasive Species (2010) and the National Strategy against the Global Change (2014). For conservation purposes of the islands, the most relevant of these national strategies are the National Strategy for the Conservation and the Sustainable Development of the Mexican Islands (2012) and the Strategy to 2040: Orientation for Conservation of the Natural Protected Areas in Mexico (2014) (see in pp. 769, CONABIO 2016).

Additionally, Mexico has signed all the International Treats of Biodiversity as the CITES (1973), General Treat of Biodiversity (1993) and Nagoya-Kuala Lumpur (2012), among others.

13.5 Federal Conservation Policy on the Islands of the Gulf of California

The total emerged surface of the islands is about 358,000 ha. A detailed list of all the efforts to protect the islands is in Ezcurra et al. (2002). All the islands have been under legal protection since 1978, first as a reserve for migratory birds and refuge of wildlife; then, in 2000, they were integrated as a federal natural protected area for flora and fauna. The programme MAB of the UNESCO recognized them since 1995, and they are listed as World Heritage Site since 2005.

For management purposes, the administration of the islands corresponds to four different natural protected areas: the Natural Protected Area for Flora and Fauna

Islas del Golfo de California of Baja California, the Natural Protected Area for Flora and Fauna Islas del Golfo de California of Baja California Sur, the Natural Protected Area for Flora and Fauna Islas del Golfo of Sonora and the National Park Bahia de Loreto.

The government and operation of all the Mexican natural protected areas (NPA) are the domain of a federal agency called CONANP (National Commission for Natural Protected Areas). Each natural protected area has a small team of technicians from this agency to manage it. Usually there is one person in charge and a reduced group of people who help that person with vigilance, fieldwork and administrative work.

It is also mandatory, by law, to establish a social assembly called advisory council (Consejo Asesor) in each NPA, with representatives of every social group involved with the protected area (local inhabitants, fishermen, tourist operators, local politicians, researchers, environmentalist, charities, etc.). This council meets at least four times a year, and they discuss all the problems of the area. Other than that, any of the members of the council could bring a current problem or situation to the next council meeting (or to ask for a special meeting) where it will be discussed in order to adopt the necessary actions in each case.

Some of the tools that CONANP has include the Annual Program of Operation, the Program for the Recovery of Endangered Species (PROCER) and the Program for Conservation and Development (PROCODES). Usually these programs don't involve reptiles; they are mostly devoted to emblematic species or sometimes to plants. The staff visits the islands ideally on a periodic basis, and they run routine censuses of the most important species on each one; again, those species are generally birds or marine mammals, never reptiles, despite the fact that they are aware of the illegal trade of rattlesnakes and other rare species. It is more complicated for the NPA staff to census reptiles in general, and snakes in particular, as they lack the expertise, and it is best done at night as most of the snakes are nocturnal.

13.6 NGO Organizations Working on Conservation

There are several NGOs working in the Gulf of California. Almost all of them are focused on marine conservation (whales, sharks, turtles, marine lions, coral, etc.), on to protect the sea from overfishing, or on bird conservation. Some others are focused on eco-tourism, and a few have an interest in land ecosystems. Of these, again, the majority works mainly with emblematic species like birds or plants, never with reptiles which are a forgotten group. We would highlight 'Conservación de islas', which is an NGO that works on eradication of invasive species, and they have had several successful cases on the Gulf islands (Aguirre-Muñoz et al. 2008), http://www.islas.org.mx/index.php?mod=qh&op=conseco.

13.7 Current Conservation Status and Perspectives

The reality is that being such a huge inhabited area, with no regular surveillance, it is very difficult to assess the status quo of the biodiversity in general or the reptile diversity in particular, or to detect the problems, until they are very urgent or very serious. The general status of the islands is good, mainly because of the low human visitation rate. However, it is very important to increase the vigilance in those which are close to the coast and are the most visited (Espiritu Santo, La Partida, Coronados, Cerralvo, Tiburon, San Pedro Nolasco, Carmen, San Jose). In Espiritu Santo, for instance, the rate of visitors has doubled in the last few years. It was more than 20,000 visitors in 2009 (Hernández-Trejo et al. 2012), and the impact of that people on the terrestrial ecosystem hasn't been evaluated (López-Espinosa de los Monteros 2002). There is also an increasing pressure to built permanent infrastructure in some islands.

In Cerralvo Island, as we mentioned, the problem is the large number of goats, domestic cats and rats. Again, the effect of these exotic species on the terrestrial ecosystem hasn't been evaluated.

In general, the conservation status of the reptile populations of the islands is virtually unknown. Apart from the population assessment of *Sauromalus* in Angel de la Guarda and San Esteban (Case 2002), there are some studies about ecology, as the diet of *Crotalus catalinensis* (Avila-Villegas et al. 2007), morphological variation in *Crotalus* (Meik and Pires-daSilva 2009) and allometric variation in size of *Crotalus mitchellii* in the islands (Meik et al. 2010); some behavioural studies of *Ctenosaura* and *Aspidocelis* (Carothers 1981; Blázquez et al. 1997; Delibes and Blázquez 1998; Delibes et al. 2015), but only Venegas et al. (2008) working on Coronado Island conducted a study about the habitat use and abundance of the set of lizard species on the island. More work is necessary to establish a baseline of knowledge of reptile populations of the islands; It is also neccesary to update the Mexican list of endangered species and to asses the functional role of reptiles in the local ecosystems.

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Chapter 14
Identifying Priority Areas for Conservation in Central Mexico: A Multi-criteria Approach

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Abstract Mexico has 181 federal protected areas, most of them with a clear spatial delimitation and management program, but some protected areas still do not have clearly defined limits, as is the case of the Protected Natural Resource Area (PNRA) Pabellón Basin, in central Mexico. The lack of delimitation of this reserve has resulted in loss of ecosystem functionality and environmental services. Our work addressed the identification of areas strategically important for conservation since they have been spaces with high diversity and ecosystem integrity with high values of biodiversity, hydrological significance, cultural importance, and mismanagement in the PNRA "Pabellón Basin" and its adjacent region. Based on this study, we have proposed areas for federal protection, as well as zones for conservation under state and county level. To achieve these objectives, multi-criteria assessment was applied based on a geographic information system, considering the participation of different sectors. This method allowed including physical, biological, and cultural criteria and views shared by different actors, as well as obtaining a spatial projection of the relevant areas for conservation. Two workshops were organized with the participation of 47 actors; 12 criteria were selected and prioritized, of which environmental

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heterogeneity, biological representation, and biodiversity were the three main criteria. The results showed the highest zones of the Sierra Madre Occidental, locally known as Sierra Fría (SF), the Plains and Hills of the Altiplano Zacatecano-Potosino (PHAZP), and the highest zone of the Sierra de Asientos (SA) as the areas with the highest value for conservations purposes.

Keywords Protected natural areas · Multi-criteria · Pabellón Basin · Sierra Fría

14.1 Introduction

Although much controversy has surrounded protected areas and their effectiveness for the conservation of nature (Lalasz et al. 2011; Soulé 2013), they are still regarded as one of the most important instruments of conservation (Bertzky et al. 2012; Joppa and Pfaff 2011; Scharlemann et al. 2010) since they are geographical spaces dedicated and managed through legal or other effective means to achieve conservation of nature in the long term with associated ecosystem services and cultural values (Dudley 2008; Deguignet et al. 2014).

In México the actual system of protected natural areas started at the beginning of the twentieth century with the establishment of the first national park (Melo Gallegos 2002). During the 1930s and 1940s, many natural reserves were decreed. Despite this breakthrough in conservation, their effective management stalled for decades. It was until the 1980s when a new great impulse prompted to decree more areas to protect biodiversity and ecosystems, including local population (Villalobos 2000; González Ocampo et al. 2014). Nowadays, Mexico has 181 protected natural areas, which comprise 10.7% of the national terrestrial surface and 22.6% of marine area, most of which have clearly defined zones and their management plans. However, still some protected areas do not have clearly defined limits, as is the case of the Pabellón Basin in central Mexico, which was created as Protected Forest Area in 1949 to protect water for agriculture irrigation. In 2002, this same area was recategorized as Protected Natural Resource Area (PNRA) but still without clearly defined limits and surface. The lack of delimitation of the reserve hinders the correct management and conservation of this PNRA and encourages land-use change from forest to agriculture or urban also due to lack of norms and management. This situation has resulted in loss of ecosystem functionality and environmental services causing a social concern for the efficient management of natural resources and protection of biodiversity.

In this context, our work addressed the identification of strategically important areas for the conservation of biodiversity, their natural resources, and adjacent regions to contribute to a better delimitation of these protected areas. We applied a geographical information system (GIS)-based multi-criteria decision-making approach with the participation of local and national stakeholders and academic and civil society organizations.

14.2 Study Area

The study area comprises the region where the protected area PNRA_01-Pabellón and its adjacent zones are located, which is between 21° 52′ 27.4″ and 22° 52′ 28.6″N latitude and 103° 01′ 08.40″ and 101° 59′ 06.79″ W longitude, occupying the southeastern part of the state of Zacatecas, the central-northern portion of Aguascalientes, and a small portion of northwestern San Luis Potosi, covering an area of 1,171,127 ha (Fig. 14.1).

The physiography of the western side of the area is dominated by portions of the Sierra Madre Occidental (SMO), which is characterized by a mountain chain and valleys, and on the eastern portions, the relief is defined by wide plains disrupted by scattered hills. The hydrographic network is poor; its streams are short and intermittent. The altitudinal range varies from 1500 to 3050 masl. The climate in most of the area is temperate semiarid with an average annual temperature from 18° to 22 °C and total annual precipitation of 400–500 mm. The highest mountain areas have temperate humid climate with an average annual temperature of 14 °C and maximum precipitation of 600 mm (INEGI 2015).

Forty-one percent of the land is used for agriculture, forestry, and livestock purposes. Natural grasslands are the most extended vegetation with almost 18% of the surface; they cover the plateaus of the lowest parts of the sierras with an elevation range from 2250 to 2450 masl, commonly associated with the oak forest where the most common species are *Bromus anomalus* Rupr. ex E. Fourn. and *B. carinatus* Hook. & Arn. (De la Cerda Lemus 2008). The crassicaule scrubland occupies almost 14% of the surface, which covers the lowlands of the hills and is dominated by different species of *Opuntia* Mill. (nopal cactus), mainly by *O. streptacantha* Lem., *O. durangensis* Britton & Rose, and *O. leucotricha* DC. The oak forest has also widespread vegetation within the study area that has developed in the highlands of the Sierra Fria at altitudes above 2000 masl where the most common species are *Quercus eduardii* Trel., *Q. laeta* Liebm., and *Q. potosina* Trel. The rest of the surface holds patches of several types of vegetation, such as tropical dry forest, desert scrubland, mesquites, pine-oak forest, and halophytic vegetation.

In the zone there are numerous disperse ponds and dams where approximately 20 species of freshwater fish inhabit, most of them exotic species (Martínez and Rojas Pinedo 2008) and one endemic species (*Allotoca dugesii* Bean) to Mexico and in risk. This zone of the country is one of the poorest in amphibian species since the states of Zacatecas and Aguascalientes have less than 7% of the species in the country (Parra-Olea et al. 2014); nevertheless, four species in this zone have been considered as threatened by the National Norm (NOM-059-SEMARNAT-2010) (DOF 2010), *Lithobates chiricahuensis* Platz and Mecham, *L. neovolcanicus* Hillis and Frost, *Pseudoeurycea bellii* Gray, and *Smilisca dentata* Smith and six under special protection (DOF 2010; Flores-Villela 1998; Lopéz-Vidal et al. 2008; Reynoso Rosales 2007). For reptiles a specific richness representation of 7% of the country has been reported, of which snakes are the richest group, followed by lizards and turtles (Flores-Villela and García-Vázquez 2014; Quintero Díaz et al. 2008).

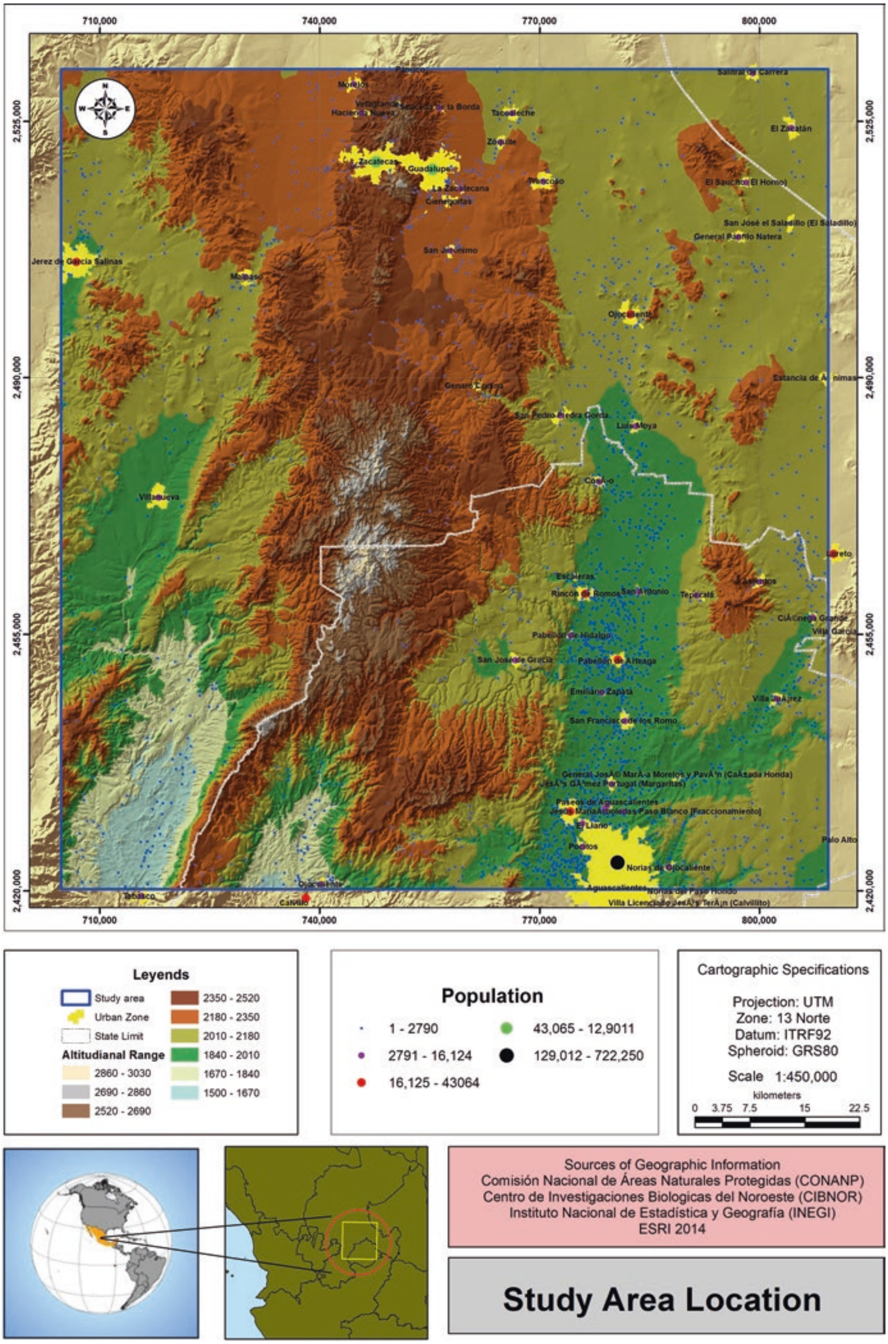

Fig. 14.1 Study area location

Birds are represented by 295 species, 49% residents and 42% migrants or wintering (WICE 2017); the presence of the golden eagle (*Aquila chrysaetos*, Linnaeus), which is considered the national bird in Mexico, has been reported in this zone.

The exact number of mammal species that inhabit the study area is not known; only for the state of Aguascalientes from 60 to 114 species were estimated (Álvarez-Castañeda et al. 2008; De la Riva Hernández 2008). However, emblematic or hunting species have been reported, such as the puma (*P. concolor* Linnaeus), bobcat (*Lynx rufus* Schreber), white-tailed deer (*Odocoileus virginianus* Zimmermann), or collared peccary (*Tayassu tajacu* Linnaeus) (De la Riva Hernández 2008).

The area has numerous archaeological remains of pre-Hispanic times as cave paintings, lithic, and ceramics, which come from different indigenous groups, generically known as Chichimecas. Moreover, numerous haciendas still exist, which were founded in colonial times and were dedicated to agriculture and livestock during the boom of silver mining by Spain.

At present the majority of the population (58%) lives in the cities of Aguascalientes, Guadalupe, and Zacatecas, dedicated to services, industry, and tourism; 26% live in small towns from 1000 to 45,000 inhabitants; the rest of the population lives in small villages and farms that engage in agriculture and livestock activities (Fig. 14.1).

14.3 Methods

In order to identify and define strategic sites for conservation (SSC), i.e., geographical spaces with high diversity and ecosystem integrity, high values of biodiversity, hydrological significance, cultural importance, and mismanagement, a GIS-based multi-criteria decision-making approach was developed, using the analytical hierarchical processes (Saaty 1980, 2008). This approach enables stakeholders to evaluate the relative priorities of conserving areas based on a set of preferences, criteria, and indicators. We conducted two workshops to obtain the criteria and their weights for fulfill the goals. The workshops involved 47 decision-makers including federal and state government sectors, experts, and civil society organizations. The criteria were selected according to physical, biological, cultural, and management aspects that permit evaluating biodiversity, ecological services, and cultural relevance of the sites, considering also the availability of basic information. The criteria have spatially quantifiable indicators, which were evaluated using GIS coupled with database and literature. All the scores were standardized; subsequently, all the criteria were hierarchized according to their weight assigned by decision-makers. For this purpose, a pairwise comparison was performed according to Satty's (1977) scale. Combining weights and the indicators, maps generated a range of values indicating the relative importance of each pixel as a strategic site for conservation.

14.3.1 Criteria, Database, and GIS

Twelve explicit, quantifiable, and mapping criteria were evaluated. Four of them were related to biological and environmental diversity; two were associated to representativeness of eco-regions; three to physical attributes and threats; and three more related to management and culture criteria. All criteria had spatial indicator representation in GIS (ArcGIS and IDRISI Taiga). To develop the indicators, basic information was used from official sources (National Commission for Biodiversity, Environmental and Natural Resources Secretary, and National Institute of Geography and Statistics); other indicators were developed by the authors according to specialized literature.

14.3.1.1 Biological and Environmental Diversity Criteria

Endangered, *threatened*, *or under special protection species per habitat:* The current rate of extinction (animals and plants) is considered by ecologists as one of the main causes of biodiversity loss (Pimm et al. 1995; Eken et al. 2004). Therefore, the decision-makers are considered important to protect the habitat with the largest number of these species. To develop the indicator of this criterion, we classified the habitat using digital maps of land use and vegetation of the area (INEGI 2013). For each of the 11 habitats, we recorded all the vertebrate, plant, and fungus species considered endangered, threatened, or protected by the official national environmental agency (NOM-059-SEMARNAT-2010) (DOF 2010) and reported by the literature (IMAE 2009; CONABIO-IMAE-UAA 2008) or digital collections from the National System of Biodiversity Information in the region (Ceballos 2002; Delgadillo Moya 2003; Fernández Nava and Arreguín Sánchez 2002; Flores-Villela 1998; García Mendoza 2003; Gutiérrez Garduño 1999; Lopéz-Vidal et al. 2008; Reynoso Rosales 2007; Sánchez Cordero 2006; Solano Camacho 2002).

Presence of the golden eagle nesting and breeding area: The golden eagle is a species in the top of the food chain, whose presence is an indicator of habitat quality; it has been considered under threatened by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Appendix II). In Mexico, in addition to its biological relevance, it is considered the most emblematic species in the country since it is the symbol of national identity (Eccardi 2008). Despite its cultural and biological relevance, the golden eagle in Mexico is considered threatened because its populations have been reduced due to habitat destruction (Rodríguez-Estrella 2002; Rodríguez-Estrella and Rivera Rodríguez 2005). Thus, the workshop participants considered relevant to incorporate spatial information about the presence of nests and hunting area for this species. To build this layer, we used the digital information about the sites where eagle nests have been reported (CONANP 2013) and also calculated a buffer area of 10,000 h as breeding zone.

Biological corridor: This criterion defined the geographical space that provides connectivity between landscapes, ecosystems, and habitats and ensures exchange or movements of populations and/or species, such as rivers, streams, canyons, and the highest zone of the watersheds. To develop this criterion, layers of hydrology and topography (INEGI 2014) were used; for each river or stream, a buffer area of 20 m was generated on each side, and the canyons and the highest area of the watersheds were selected from the topography layer.

Environmental heterogeneity: Environmental heterogeneity has been associated as one of the most important factors that influence distribution and abundance of plants and animals (Hutchings et al. 2000). A positive correlation has also been demonstrated positive between the degree of environmental heterogeneity and species diversity (MacArthur 1965; Ricklefs 1977). To attend this aspect, we developed an indicator that refers to the diversity of ecosystems per unit area. The study area was divided into a grid of 25 cells of 576 km^2 each, overlapping the vegetation layer (INEGI 2013). For each cell the ratio of the area occupied by each type of vegetation present in the area was calculated and computed with the diversity index of Shannon-Weaver; the cells with the highest value were considered more important.

14.3.1.2 Representativeness of Eco-regions

Conservation gaps and omissions: This criterion was constructed based on the information from the National Biodiversity Commission (CONABIO) and the Commission for Protected Natural Areas (CONANP for its abbreviation in Spanish), related to the poorly represented eco-regions in the system of protected natural areas (CONABIO et al. 2007), whereas those regions underrepresented in the national protection system are more important for new conservation initiatives.

Priority regions: This criterion relates to highlight regions that have been considered important for the conservation of birds (CIPAMEX-CONABIO 1999), relevant hydrologic regions (Arriaga et al. 2000), continental aquatic sites (CONABIO-CONANP 2010), and priority terrestrial areas (CONABIO et al. 2007). To build the indicators of this criterion, all layers were overlaid, of which the areas with the largest number of conservation attributes were the most important.

14.3.1.3 Physical Attributes and Threats

Catchment basin area: There is a great demand for water for urban and agricultural use in the region. That is why the surface of the basin was considered as a relative measure of water catchment. The area of each micro-basin was calculated considering that the larger the area the more importance it would have.

Degraded surfaces: This criterion was relative to exclude all degraded surfaces by human activities as urban, agriculture, open-pit mining, and roads. To build the indicator, all cities, agricultural areas, and industrial zones were excluded from the layer of land-use and vegetation (INEGI 2013). For open-pit mining information, geological information from INEGI (2012) was used avoiding the entire surface classified as mining. We also analyzed the information from the National Population Census (INEGI 2010); all the rural localities and buffer areas of 1000 m were excluded. For the area impacted by roads, we used the information of the road network of the area (INEGI 2014) and shaped a buffer zone of 250 m for each side of the path.

Environmental management units with exotic species: The environmental management units (EMU) are rural areas delimited for legal use of wildlife; they have a management program and are recognized by the environmental authority; however, some of them include exotic species. Because participants considered exotic species as a threat for the biodiversity, these areas were excluded from the analysis. The digital map of the EMU was obtained from the Wildlife Office (SEMARNAT 2015) and the information of the presence of exotic species from field trips by the staff of the National Commission of Natural Protected Areas.

14.3.1.4 Culture and Management

Cultural heritage: This criterion included sites with archaeological and paleontological remains. The information was obtained from the National Institute of Anthropology and History (INAH 2014). Areas with the presence of such characteristics were considered as the most important.

Areas susceptible to payment for ecosystem services: This criterion included all the surfaces incorporated in the payment programs for environmental services (carbon and hydrologic) given by the National Forestry Commission (CONAFOR 2014). Such places were considered as important to conservation.

Areas with support for restoration: This criterion included surfaces that have support from the government or social organizations for soil restoration and establishment of nurseries and forestry plantations; the basic information was obtained from the National Forestry Commission. The areas with restoration support were considered as important for conservation.

14.4 Results and Conclusions

As a result of the criterion pairwise comparison by decisions-makers, environmental diversity was weighed with the highest value, while the presence of exotic species had the lowest one (Fig. 14.2).

Based on the hierarchical values for each criterion, we proceeded to add the weighted value of each criterion in each of the pixels of the study area, using the decision support models of IDRISI Taiga (Clark Labs 2009). According to this procedure, 10% of the area resulted as very important for conservation, while 45% appeared with little relevance for these purposes (Fig. 14.3). The most important areas were the highest zones of the Sierra Madre Occidental, which is locally known

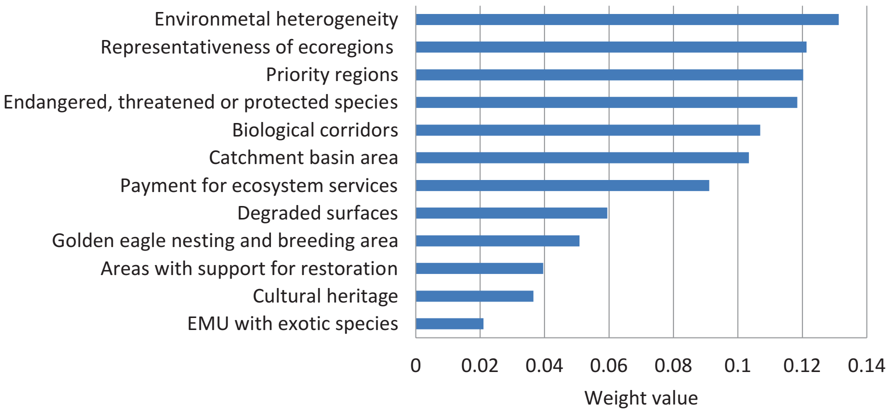

Fig. 14.2 Priority weight for the criteria

as Sierra Fría (SF), Plains and Hills of the Altiplano Zacatecano-Potosino (PHAZP), and the highest zone of the Sierra de Asientos (SA) (Fig. 14.3).

The SF concentrates the oak and the oak-pine forest which are the ecosystems with the highest number of species under protection (Fig. 14.4); this mountain chain turned out to be also very important for the provision of hydrological environmental services and carbon sequestration because it is the area of the greatest altitude (>3000 m) and precipitation in the zone, as well as the region with the highest vegetation cover.

The Sierra Fría is also considered an important bird area (CIPAMEX-CONABIO 1999) where 13 species of birds live considered as endangered or under special protection, such as the golden eagle, peregrine and prairie falcons, and spotted owl.

The Plains and Hills of the Altiplano Zacatecano-Potosino (PHAZP) correspond to a low mountain range within the Altiplano region, which is considered poorly represented in the Protected Natural Area System (CONABIO et al. 2007). This area also has a high environmental heterogeneity since there are seven different vegetation types in an area of 600 km^2 with an important value as biological connectivity because it includes a low sierra in the area.

The Sierra de Asientos has been considered an important region for conservation since it represents a gap area in the official programs for biodiversity conservations (CONABIO et al. 2007); it also contains crassicaule scrubland that is ranked as the third most important ecosystem for the number of endangered, threatened, and protected species; this area was considered relevant as a biological corridor since it is a mountain range with a continuous vegetation cover, besides being a relevant area because of the presence of golden eagle nests and numerous pre-Hispanic archaeological sites.

Based on these results, we have proposed these three areas to be included in the system of protected natural areas. Because of the extension and relevance of the Sierra Fria, it must be included as a protected area of national relevance, while the

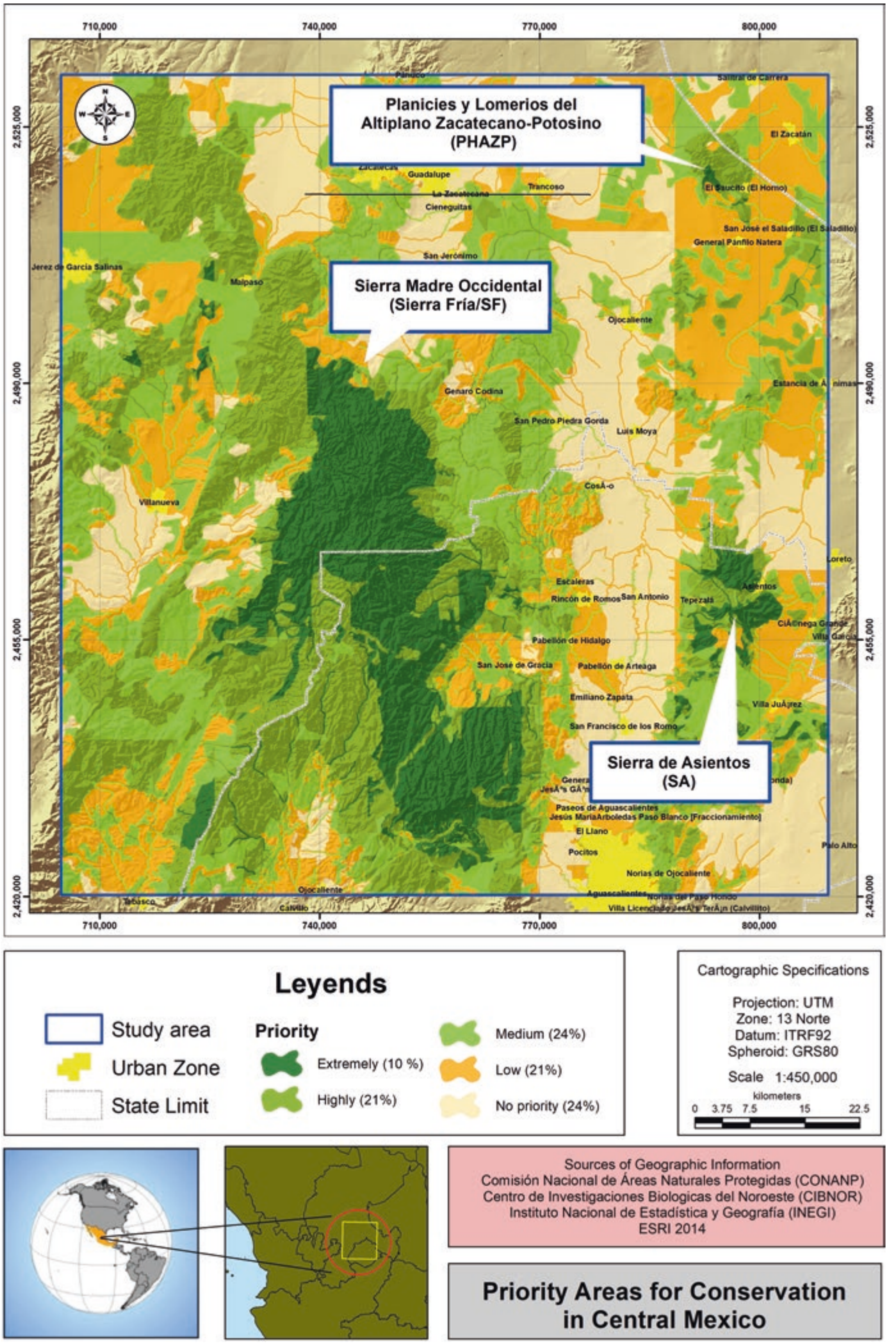

Fig. 14.3 Priority areas for conservation

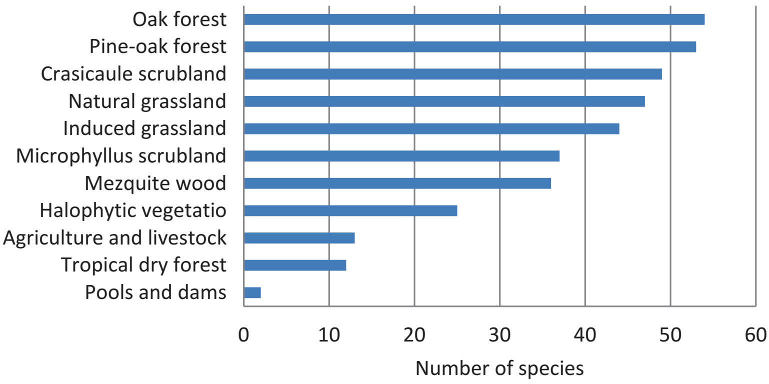

Fig. 14.4 Number of species under protection per ecosystem

Plains and Hills of the Altiplano Zacatecano-Potosino and the Sierra de Asientos should be as state protected area or at municipal level.

The geographical information system (GIS)-based multi-criteria decision-making approach has been an important tool to prioritize sites for conservation since this method allowed incorporating various criteria (physical, biological, and cultural) shared with different views of the stakeholders, as well as obtaining a spatial projection of the relevant areas for conservation. Despite the usefulness of this method, relatively few studies are available related to forest conservation that used the multi-criteria decision-making approach with GIS techniques (Phua and Minowa 2005).

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Chapter 15
Potential Impacts of Decadal Climate Variability on Coastal Biodiversity and Societal Important Productive Activities: A Case Study in Mexican Coastal States

Isaac Azuz-Adeath and Alejandra Cuevas

Abstract This chapter shows the influence and potential impacts of decadal climate variability on Mexico's coastal biodiversity, fishery, and agricultural production, using the temporal structure of several modes of climate variability relevant for the northern hemisphere, the Atlantic Multidecadal Oscillation (AMO), the Pacific Decadal Oscillation (PDO), and the North Atlantic Oscillation (NAO), as well as climatic variables time series (precipitation, maximum, and minimum temperature). An evaluation of the historical and potential effects of this natural climate variability is presented for the 17 Mexican coastal states. The results show a clear influence of the climatic variables and the different modes of climatic variability on the agricultural production in all coastal states, with the highest positive correlation between AMO and lemon production in Colima state (r = 0.87) and maximum negative between NAO and sorghum production in Tamaulipas state (r = −076); an influence on forestry production for some coastal regions – like Oaxaca state; as well as its impact on the natural vegetation cover changes and consequently on biodiversity. The need for systematic, regular, and long-term monitoring processes of climatic variables, coastal resources of economic value, and biodiversity are key elements for generating knowledge and establishing adaptation and mitigation measures for climatic phenomena of the order of decades and larger time scales.

Keywords Climatic variability · Agricultural production · Decadal behavior · Biodiversity

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15.1 Introduction

Mexico is considered a mega-diverse country (UNEP/CBD 2002, 2016), part of the group of countries with 70% of global biodiversity. This rich biological diversity is mainly due to its location with coast in both the Atlantic and the Pacific oceans; latitudinal extension (14–32° north); continental, insular, and maritime size (approximately 7 million square kilometers); physiographic variety, 15 physiographic regions from sierras to coastal plains; geomorphology including 2 peninsulas and 2 semi-enclosed seas, the Sea of Cortez and the Gulf of México; and climatology (from humid to desert). The Mexico's coastal zone has a coastline extension of 11,200 km and includes most of the coastal environments such as sandy, muddy, and rocky coast, wetlands, estuaries, coastal lagoons, tidal inlets, deltas, barrier coasts, and several coral reef areas with the second largest in the world.

Three administrative levels operate in the coastal areas of Mexico: the federal (national) level, the state (region or province) level, and the municipality (local) level; all these governmental levels have legal, regulatory, managerial, and planning responsibilities over the coastal zone, which often overlaps and frequently finds problems (e.g., regulatory, economic, technical capacities) to implement long-term projects or actions. The federal interministerial body in charge of the biodiversity in Mexico is the National Commission for the Knowledge and Use of Biodiversity (CONABIO) but also the Ministry of Environment (SEMARNAT), the Ministry of Food and Fisheries (SAGARPA), the Ministry of Development and Planning (SEDATU), the Ministry of Tourism (SECTUR), and governmental research institutes like the National Institute for Ecology and Climatic Change (INECC), among many other official bodies that have responsibilities and powers to act in the coastal zone.

The population growth (Fig. 15.1) and the associated urban expansion, pollution, soil use changes, and loss of ecosystem services, as well as the need to have infrastructure, resources, and employment, are among the main pressures in Mexico's coastal zone. Shared between 17 coastal states, in the Mexican coastal zone live 55.3 million people (INEGI 2017). The population attraction to the coastal zones is mainly due to the economic opportunities, most of them related with port, industrial, and touristic activities. As an example, Quintana Roo State, in the southern part of Mexico and surrounded by the beautiful Caribbean Sea, is located in a highly risk area (i.e., a barrier island in the path of the Atlantic cyclones) which makes the population and infrastructure very vulnerable to extreme meteorological events, erosion, and flooding. However, the largest number of cruise ship arrivals and hotel rooms in the country can be found in this coastal state. In Quintana Roo, the population in 1960 was 50,169 inhabitants; in one generation (55 years), the population grew up to 1.5 million people (INEGI 2016), making very difficult the planning processes and the rational conservation of the coastal environment, their ecosystem services, and its biodiversity.

Historically, Mexico has been among the top 20 countries in fishing production; this is one of the reasons why we concentrated this chapter on Mexico's coastal

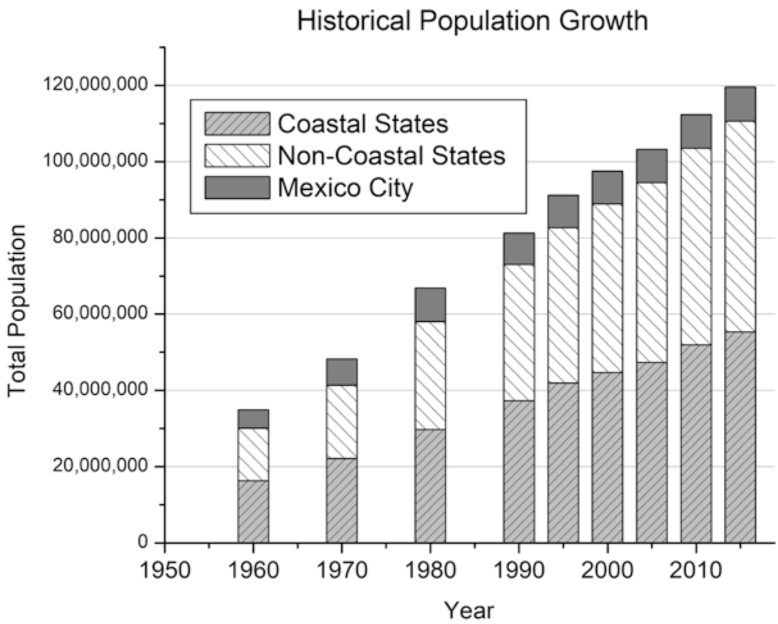

Fig. 15.1 Population growth in Mexican coastal states (gray with pattern), non-coastal states (white with pattern), and Mexico City (dark gray). (Source of data: INEGI 2016)

zone, but also, because nearly 66% of the agricultural production value in Mexico emanates from its 17 coastal states, 15% from the East coast (6 states), and 51% from the West coast (11 states). Primary economic activities like agriculture, fishing, forestry, or livestock in Mexico represent only a small fraction of the total gross domestic product (3.3% in 2015); however, a high percentage of this value comes from the production in Mexican coastal states (INEGI 2017). Besides the marginal contribution to the total economy, locally, the primary sector is an important source of employment and food for the less favored families. On the other hand, the oil production as a secondary economic activity is fundamentally an activity that takes place in the coastal states. In 2015, the revenues from only two coastal states (Campeche and Tabasco) represented 90% of the national total (INEGI 2017). The income associated with hotel and restaurant services (tertiary economic activities) in coastal states represents 58.5% of the national value. Only three states, the most important in terms of tourism facilities – Baja California Sur (BCS), Guerrero (GRO), and Quintana Roo (QROO) – contribute with 24% of the total (INEGI 2017). With data of the third trimester of 2017, the national average unemployment rate was 3.55% (INEGI 2017) and for the coastal states 3.26%; 9 of 17 coastal states were below the national value. These economic data suggest good development possibilities and quality of life for coastal inhabitants, which could be assessed by the poverty-level measurements (see Fig. 15.2) made by the National Council for the Evaluation of Social Development Policy (CONEVAL 2016), in which 11 coastal states are below the national average. However, several of the most biodiverse

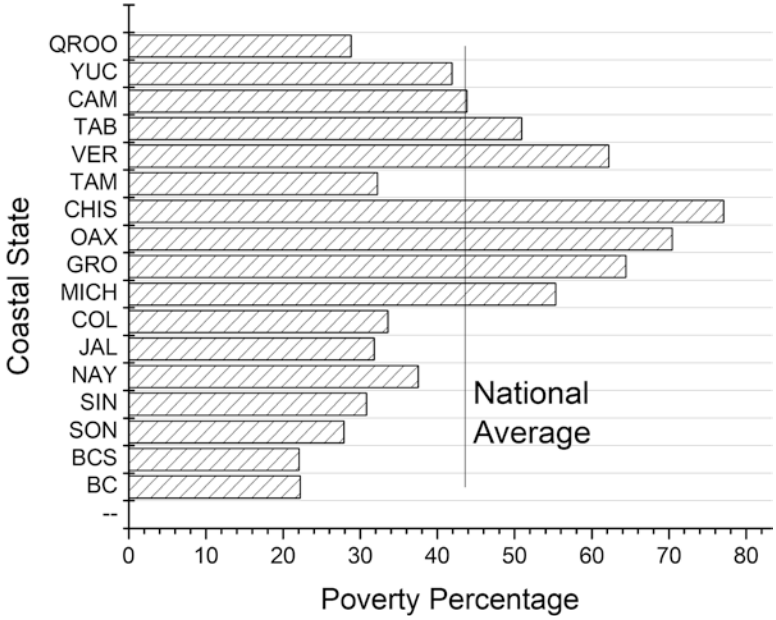

Fig. 15.2 Poverty level in Mexican coastal states. Percentage of people living under poverty conditions. (Source of data: CONEVAL 2016)

states like Chiapas (CHIS), Oaxaca (OAX), Guerrero (GRO), and Veracruz (VER) are well above the national mean.

One mechanism established by the Mexican government to alleviate poverty and preserve the natural capital, biodiversity, and ecosystem services and functions is the payment for temporal employment (PTE) related with environmental issues. The accumulated amount that has been paid to the coastal states during the 2008–2012 periods associated with wildlife conservation, water management, ecotourism, solid waste management, prevention of fires, restoration of natural soils, reforestation, environmental education courses, and surveillance of natural resources is presented in Fig. 15.3.

In general, the natural terrestrial capital and biodiversity of the Mexican coastal states could be considered one of the biggest in Mexico. The highest numbers of several species in the country such as pteridophytes, gymnosperms, angiosperms, amphibians, reptiles, birds, and mammals are located in states of the coastal region (SEMARNAT 2014). The largest densities of endemic species occurred in the study area, most of them in the Pacific coast (Koleff and Soberón 2008; SEMARNAT-DGEIA 2016), and six of the seven terrestrial ecoregions in Mexico could be observed (INEGI-CONABIO-INE 2008). Specifically, the coastal states Veracruz (VER), Oaxaca (OAX), and Chiapas (CHIS) have the highest number of arthropods, vascular plants, and vertebrate species in the country (Llorente-Bousquets and Ocegueda 2008; SEMARNAT 2013).

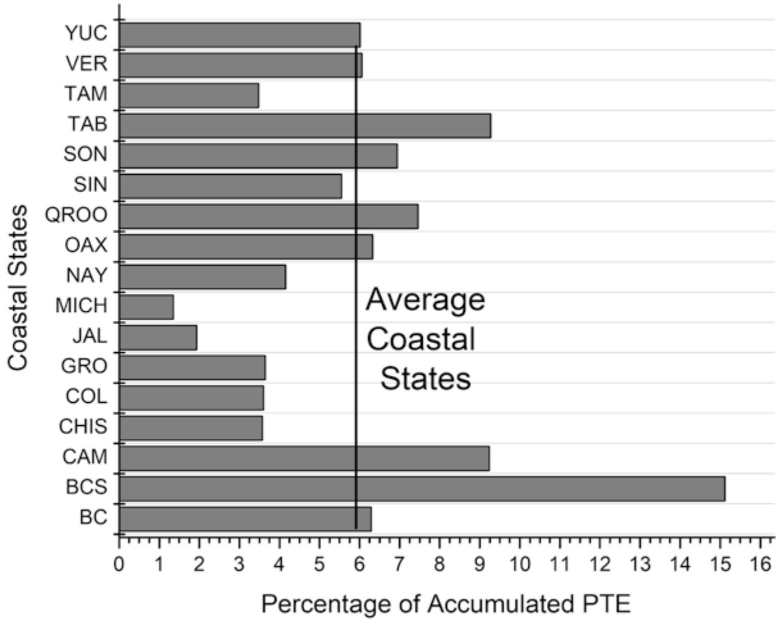

Fig. 15.3 Percentage of the accumulated amount payed from temporal employment related with environmental issues to the Mexican coastal states during the period 2008–2012. (Source of information: DGPAIRS-SEMARNAT 2014)

One of the most important elements for biodiversity conservation considered by the Mexican environmental law is the possibility to create and manage natural protected areas (NPAs). The establishment of protected areas around the world has been recognized as a cornerstone process to preserve global biodiversity, ecological integrity, environmental services, and livelihoods which bring direct benefits to the human population (Ervin et al. 2010; Pullin et al. 2013). In Mexico, the economic and social benefits related to the creation of protected natural areas have been evaluated and documented among others by Bezaury (2009), Bezaury-Creel and Gutiérrez (2009), and Méndez-Barrera (2012); the effectiveness of natural protected areas in preventing land use and land cover changes has been documented extensively by Figueroa and Sánchez-Cordero (2008) and Blackman et al. (2015); the territorial extension, geographic distribution, and managerial status of the Mexican NPAs could be found in CONANP (2016); and several site-specific, threat-oriented, management-focused, or species-/ecosystem-oriented researches could be found among many others in Carr (2007), Méndez-Contreras et al. (2008), Durand and Lazos (2008), Lara-Lara et al. (2008), Coates et al. (2015), and Ávila-Canto et al. (2017).

In 2016 a very important increase in the extension of NPAs occurred in Mexico, adding 43.6 million (Ha) with the decree of two marine NPAs the “Deep Mexican Pacific” and the “Caribbean.” Actually the country has 182 federal NPAs that cover 90.8 million hectares (CONANP 2017). Considering only the NPAs located in the 17 coastal states, the territorial extension of the federal NPAS covers 13.4 million hectares (Ha), from which 9 million (Ha) corresponds to coastal municipalities. The specific information can be observed in Fig. 15.4a, b.

If we include the marine, coastal, and island environment, the total dimension of the NPAs is 77.4 million (Ha) from which 54.5 million (Ha) is strictly marines. The distribution of the surface covered by these NPAs according to the official classification as (a) biosphere reserve, (b) national park, (c) protected areas of flora and fauna, and (d) sanctuary could be seen in Fig. 15.5.

This chapter is focused on the influence of decadal climate variability on coastal biodiversity and societal important activities like agriculture and fishery. We analyzed the influence of several of the most prominent modes of climate variability that manifest in the northern hemisphere, the Atlantic Multidecadal Oscillation (AMO), the North Atlantic Oscillation (NAO), and the Pacific Decadal Oscillation (PDO) through the behavior of their temporal indexes. The spatial and temporal structure of the NAO has been widely described in the National Center for Atmospheric Research (NCAR 2017); in the same way, the behavior of the AMO and PDO can be observed – among others – in the information presented by Deser et al. (2010), KNMI (2017), NOAA-ESLR (2017), and JISAO (2017).

Around the world, extreme climate events, climate variability, and climate change will affect biodiversity, agriculture, fisheries, forestry, and livestock, which in conjunction with other environmental, social, political, and economic factors increase the risk and vulnerability to economic losses and ecological disasters in several regions and countries (Zhao et al. 2005; Sivakumar et al. 2005; Parry et al. 2007; Field et al. 2014). Significant simultaneous correlations between the temporal fluctuations of meteorological parameters, from seasonal to multi-decadal time scales, at widely separated points of the earth or teleconnections (Karoly 1983), might induce natural climate global signals or modes of climate variability like the AMO, NAO, or PDO in the northern hemisphere, inducing and influencing precipitation and river flow variability (Enfield et al. 2001; Benson et al. 2003; Ouachani et al. 2013); freshwater and heat content changes in the ocean (Boyer et al. 2007); anomalous surface temperature patterns; irregular fishery production (Mantua et al. 1997; Tian et al. 2011); abnormal landfalls of major hurricanes (Poore and Brock 2011); atypical forest growth rates and risk of fire (Mote et al. 2003); and scarcity of water resources and vulnerability on agricultural systems (Motha and Baier 2005; Piao et al. 2010; Rosenzweig 2011), among other variables and processes in widely extended and separate regions and continents.

In the following sections, we explain the data and methodology used to assess the influence of long-term (decadal) climate variability on coastal biodiversity, agriculture, and some selected species of fishery products; then the analysis of climate variables and modes of climate variability over the study area are presented, and finally the last section shows the influence of these phenomena on Mexican coastal zone.

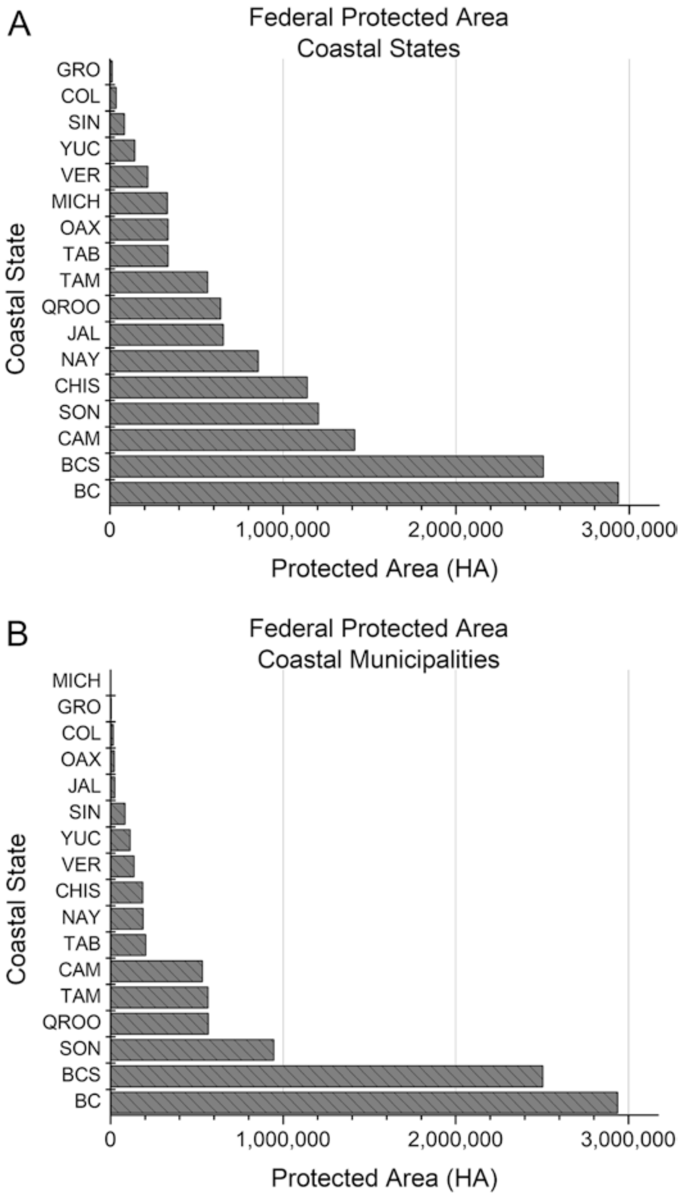

Fig. 15.4 Federal NPAs in Mexican coastal states (**a**) and NPAs in coastal municipalities (**b**)

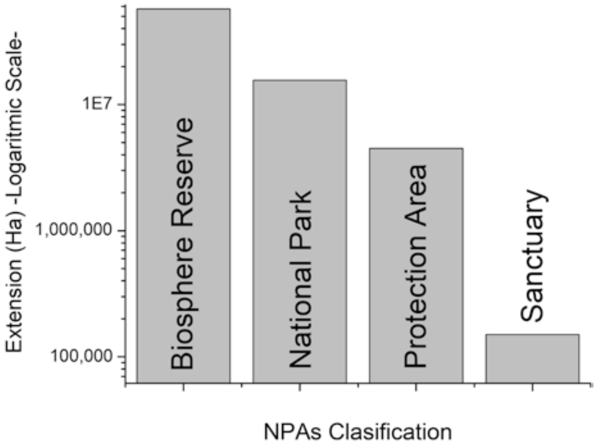

Fig. 15.5 Territorial extension of the NPAs in marine, coastal, and island environments. (Source of data: CONANP 2017)

15.2 Methodological Framework

15.2.1 Study Area

Mexico has a territorial extension of 7 million km^2, from which 1.9 million corresponds to terrestrial areas and 5.1 million to marine zones (see Fig. 15.6). The country poses around 11,122 km of coastline, shared among 17 coastal states and 156 coastal counties (smallest administrative unit). According to Silva et al. (2014), sandy beaches comprise 75.7% of the total Mexican coastline. These beaches are worldwide recognized by their beauty, and domestic and international visitors enjoy the activities associated with the use of their coastal and marine areas. However, increasing population growth rates in the coastal zone, urban expansion, massive tourism, land- and marine-based pollution, climate-related impacts, changes of soil use, and losses of biodiversity and ecosystems services seriously threaten its sustainable development (Azuz et al. 2018).

This study is focused only on the 17 Mexican coastal states because they are strongly influenced by the climatic land-ocean-atmosphere interactions. From north to south and from west to east, those states are Baja California (BC), Baja California Sur (BCS), Sonora (SON), Sinaloa (SIN), Nayarit (NAY), Jalisco (JAL), Colima (COL), Michoacán (MICH), Guerrero (GRO), Oaxaca (OAX), and Chiapas (CHIS) in the West coast, surrounded by the Pacific Ocean and Cortés Sea, and Tamaulipas (TAM), Veracruz (VER), Tabasco (TAB), Campeche (CAM), Yucatán (YUC), and Quintana Roo (QROO) in the east basin, bounded by the Gulf of México and Caribbean Sea (see Fig. 15.6).

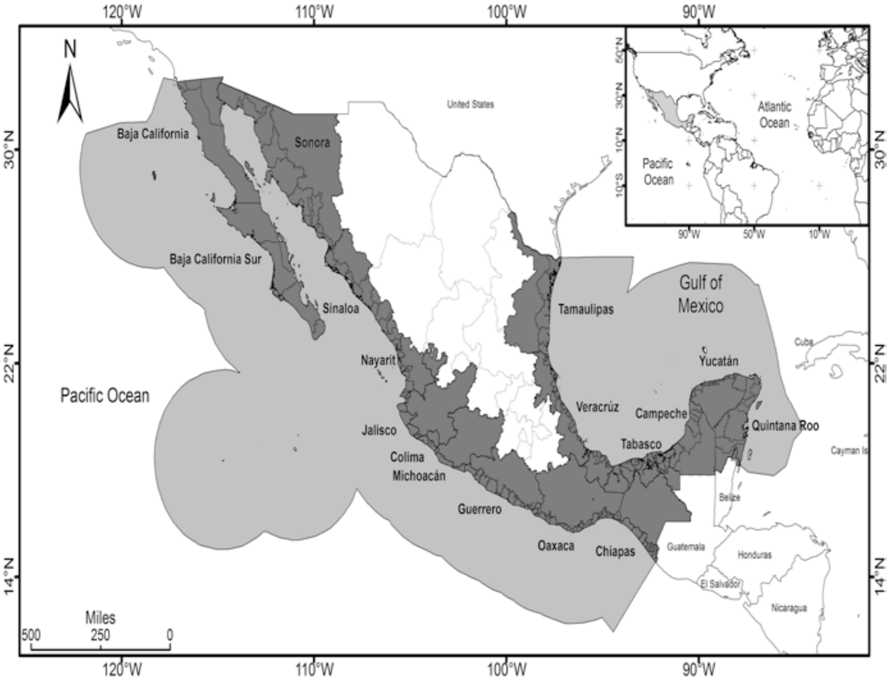

Fig. 15.6 Study area. Mexican coastal states and counties (dark gray) and marine extension (light gray)

15.2.2 Data

This study uses yearly information for the period 1980–2015 for each coastal state in the following variables:

(a) Spatially average maximum and minimum atmospheric temperature, from the National Weather Service (SMN 2017).
(b) Yearly accumulated rain, from the National Weather Service (SMN 2017).
(c) Total agricultural production, from the Information System for Food and Agriculture (SIAP 2017).
(d) Total production for the three most important agricultural products in each coastal state according to their economic value in 2010 (SIAP 2017). The selected products in each state were tomatoes, wheat, and strawberry (BC); tomatoes, chili, and potatoes (BCS); wheat, grape, and potatoes (SON); maize, tomatoes, and chili (SIN); sugarcane, beans, and mango (NAY); maize, sugar-cane, and pastures (JAL); lemon, sugarcane, and pastures (COL); avocado,

maize, and blackberry (MICH); maize, mango, and pastures (GRO); maize, pastures, and sugarcane (OAX); maize, pastures, and coffee (CHIS); sorghum, sugarcane, and maize (TAM); sugarcane, maize, and orange (VER); banana, sugarcane, and cocoa (TAB); maize, sugarcane, and soybeans (CAM); pasture, maize, and lemon (YUC); and sugarcane, maize, and chili (QROO).

(e) Yearly catches of selected fishery products reported in each coastal state, from the National Fishery Commission (CONAPESCA 2017).

The mangrove surface in each coastal state was defined using as a bottom line several surveys from 1970 to 1980 and regular observations from 2005, 2010, and 2015 (Valderrama-Landeros et al. 2017).

The natural vegetation cover, its rate of change, and the environmental status in each coastal state were calculated using information from 1993, 2002, 2007, and 2011 (POEGT 2012).

Direct monthly values were used to obtain yearly average values for the period 1980–2015 in the following global climatic signals or modes of climate variability:

(a) Atlantic Multidecadal Oscillation (AMO index): Unsmoothed time series from the Earth System Research Laboratory (NOAA-ESRL 2017)
(b) North Atlantic Oscillation (NAO index): Time series from the Climate Prediction Center (NOAA-CPC 2017)
(c) Pacific Decadal Oscillation (PDO index): Time series from the Joint Institute for the Study of the Atmosphere and Oceans, University of Washington (JISAO 2017)

15.2.3 Methodology

To investigate the potential effect of decadal climate variability on Mexican biodiversity, agriculture, and fishery, this study followed a correlational approach in periodical records (i.e., climate variables, modes of climate variability, agriculture production, fishery catches) in which:

(a) The time series of climatic variables (i.e., maximum and minimum temperature, rain), agriculture, and fishery production for each coastal state were linearly detrended to extract the possible contribution of climate change (e.g., global warming) or anthropic influence (e.g., better harvest technology, pest control, fishing capture effort, etc.) from the original data. The resulting signal (i.e., residual part) was smoothed twice using adjacent average method with a period of 5 years to make the lower-frequency signals visible.
(b) The time series of the indices associated with the modes of climatic variability used in this study (AMO, NAO, PDO) were also detrended to avoid the influence of ascending or descending slopes related with the long-term behavior of the global signal, for example, the AMO has a high-energy band with period of 70 years, and the residual part was also twice smoothed with a 5-year period.

(c) The resulting time series were correlated to observe the direction and strength of the relationship among all selected variables.

For the nonperiodical records (e.g., mangrove extension, natural vegetation coverage, soil degradation, environmental condition of the territory), descriptive measures were obtained with direct data and using rates of change.

Knowing the existing relationships between the climatic variables, the global signals, and the products of social importance of each coastal state during the period of analysis, we proceeded to contrast this information against the changes observed in the nonperiodic signals related to natural elements and biodiversity.

15.3 General Results

15.3.1 Climatic Unsmoothed Variables (Yearly Values)

Considering 36 years of rainfall observations (1980–2015), six coastal states show a statistical significant ($p < 0.05$) positive slope in their linear trend, while the remaining 11 show nonsignificant increase (6) or decrease (5) in rainfall level trends. The state with the greatest changes was Colima on the central Pacific coast, going from 860 mm in 1980 to 1956 mm in 2015 (see Fig. 15.7).

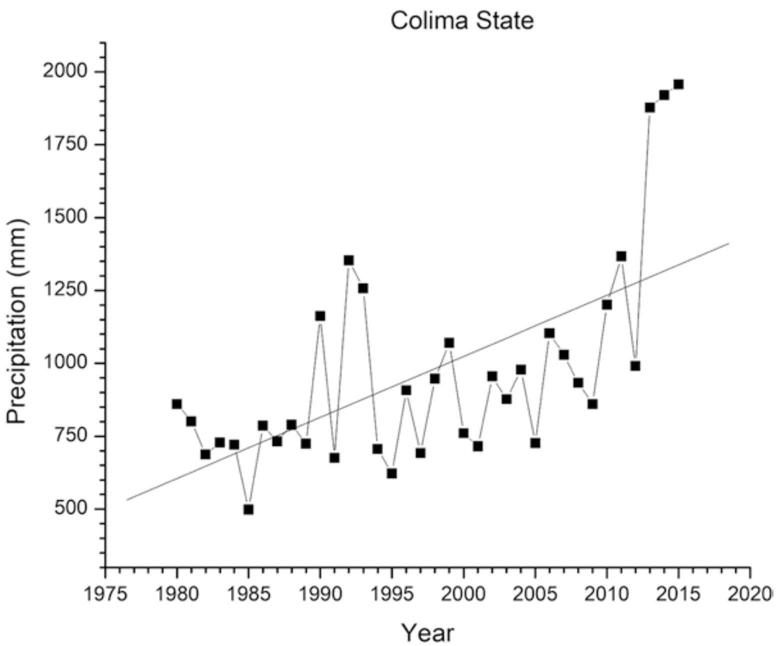

Fig. 15.7 Historical rain (mm) in Colima state

Table 15.1 Yearly accumulated rain (mm) in Mexican coastal states during decadal periods

	Analyzed period			
Coastal state	1980–1989	1990–1999	2000–2009	2010–2015
BC	249.10	197.20	174.30	199.33
BCS	181.80	189.80	191.60	234.87
SON	453.50	428.40	382.50	461.00
SIN	736.60	734.00	642.10	776.65
NAY	954.60	1211.60	1180.70	1297.43
JAL	777.10	789.40	784.80	900.20
COL	732.60	939.10	893.60	1552.13
MICH	752.60	708.00	841.20	914.63
GRO	1045.20	950.90	1089.20	1195.72
OAX	1423.10	1459.10	1472.20	1352.42
CHIS	1856.90	1709.40	2130.60	2178.85
TAM	724.80	809.80	813.60	879.77
VER	1304.70	1587.90	1658.80	1653.25
TAB	2253.40	2241.20	2302.40	2460.05
CAM	1106.90	1356.40	1469.40	1360.13
YUC	1143.80	1081.30	921.10	1089.73
QROO	1223.10	1357.80	1305.70	1511.73

To avoid the potential influence of short-term (monthly to yearly) meteorological phenomena (e.g., tropical storms, hurricanes, hurricane season), a decadal analysis was performed considering the average precipitation during the periods 1980–1989, 1990–1999, 2000–2009, and 2010–2015. A negative difference (decrease) between the first and the last period studied was observed in three coastal states (BC, OAX, and YUC); the largest decrease was observed in Baja California (BC) with a deficit of 50 mm (20% below the decadal average for the period 1980–1989). On the other hand, 14 coastal states show increases in the rain volume from 1980–1989 to 2010–2015. Of these 14 states, 4 presented levels higher than 300 mm in the years of the present decade (NAY, COL, CHIS, and VER). The decadal information related with this analysis could be observed in Table 15.1.

The behavior of surface atmospheric temperature on coastal states was analyzed using two variables, the maximum and the minimum temperature. For the yearly maximum temperature, only seven records show a significant ($p < 0.05$) positive slope (temperature increase) in the regression analysis (BC, SON, SIN, NAY, OAX, CHIS, TAM), most of them in the West coast. Regarding the minimum temperature, a completely different scenario emerged; 14 of the 17 states presented significant positive slopes (temperature increase). The states with a coefficient of variability (standard deviation/average) in the minimum temperature above 10% were Baja California (BC) and Oaxaca (OAX); their historical comportment could be seen in Fig. 15.8.

In general terms, 8 out of 17 coastal states experienced an important jump in the minimum temperature between 2003 and 2005, such as Oaxaca state which experienced an increase of 3 °C between 2003 and 2004 or Baja California which

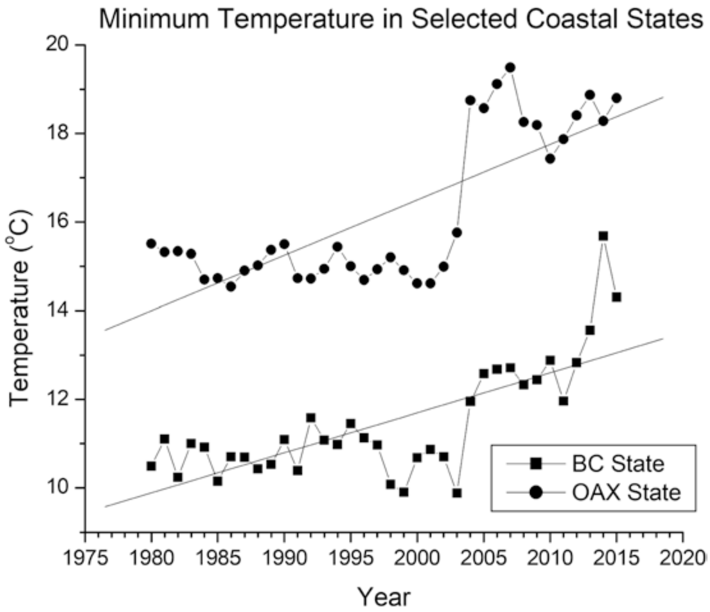

Fig. 15.8 Historical behavior of the minimum temperature (°C) in two Mexican coastal states

showed a rise of 2 °C during the same years (see Fig. 15.8). Also in ten coastal states (59%), the last year recorded (2015) presented the highest minimum temperature value of the entire record.

15.3.2 Climatic Smoothed Variables (Decadal Values)

The main objective of this research is the analysis of the potential impacts of long-term (decadal) climate variability on coastal biodiversity and societal important activities that occur in the coastal area. In this sense, the following materials – smoothed time series – present the behavior of the low-frequency part of the signals for the studied variables.

The rainfall data show a clearly low-frequency oscillatory variability with values above (positive phase) and below (negative phase) of the trend. The number of waves observed inside the analysis window (1980–2015) varies from one to two and a half. The location of the valley and crest of the waves vary from region to region; 11 coastal states ended (2015) with a positive phase (7 from the West coast and 4 from the East) and 6 with a negative phase (4 from the West coast and 2 from the East). Figure 15.9 shows the behavior of two selected coastal states in which the number of waves present and the location of maximum and minima differ, as well as the number of years during which they remained in each phase.

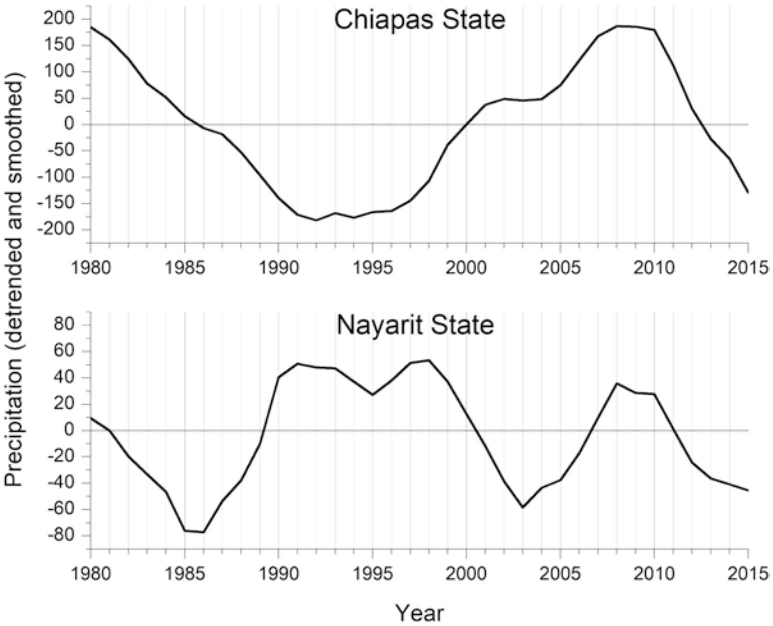

Fig. 15.9 Low-frequency (smoothed signal) precipitation behavior in two selected coastal states: Nayarit (bottom) and Chiapas (top) from the West coast

The similarity of the decadal behavior of the rain between coastal states was evaluated using correlation techniques; 78 of the 136 possible correlations (57.4%) were statistically significant ($p < 0.05$). The two highest positive and negative correlations occur among geographically separated states: SIN and YUC ($r = 0.94$), JAL and TAM ($r = 0.92$), SON and OAX ($r = -0.92$), and JAL and OAX ($r = -0.92$). Figure 15.10 shows some of these correlations.

The other relevant factor in this analysis is the percentage of variability explained by the decadal signals. In this sense, important results emerged; in average, between 40% (rain) and 60% (minimum temperature) of the original variability could be assigned to the low-frequency part of the signal. This fact has profound implications in terms of the potential impacts of long-term climate variability on coastal biodiversity and several economic activities that are developing using natural resources from those areas. Table 15.2 shows the standard deviation values of the original (unsmoothed) and smoothed (long-term variability) signals together with the percentage of variability explained by this last series of data.

The decadal behavior of the maximum and minimum temperature also exhibits an oscillatory pattern with positive phases (increase in temperature) and negative phases (decrease in temperature). Regarding the maximum temperature, on the West coast, four states ended (2015) in positive phase, while on the East coast, they were three. In the case of minimum temperature, all the coastal states in both coasts ended in positive phase. The spatial patterns show similarities between coastal

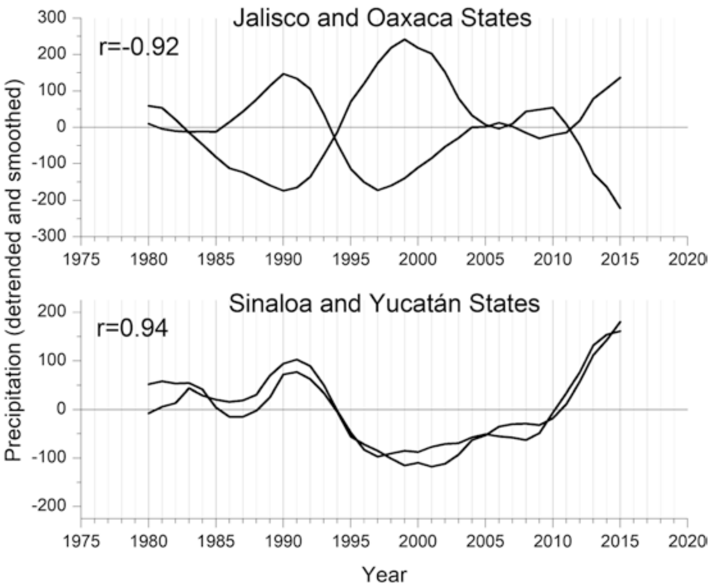

Fig. 15.10 Highest correlation values between low-frequency rain signals in separate coastal states: SIN and YUC (bottom) and JAL and OAX (top)

states: for the maximum temperature, 96 of 136 (70.6%) significant ($p < 0.05$) correlations were observed and for the minimum temperature 113 of 136 (83%). The highest correlations found can be observed in Fig. 15.11.

15.3.3 Modes of Climate Variability

The analysis of the correlations between the climatic variables registered in the different coastal states and the signals associated with the modes of climatic variability without smoothing (annual values) presented 40 significant values ($p < 0.05$) of the 153 calculated (26%). The most influential mode of climate variability in this case was the AMO with 23 significant correlations, 22 of them positive and 1 negative; the variable that was most influenced by this mode of climatic variability was the minimum temperature (nine significant correlations, four of them in the West coast and five in the East). The variable that had the least influence was the NAO (seven significant correlations), and its effect was felt mainly in rainfall patterns (six significant correlations). The strength of the relationship between climatic variables and modes of climatic variability using annual values in general can be classified as medium, with values ranging from $r = 0.65$ to $r = -0.45$.

In the case of decadal behavior, the results were much better. There were 72 significant correlations, 35 with the AMO, 21 with the NAO, and 16 with the PDO. Not only the number of correlations increased (47%) but also the strength of

Table 15.2 Variability of the original signals explained by low-frequency signals (decadal component)

	Precipitation			Maximum temperature			Minimum temperature		
Coastal state	Original data (STDEV)	Smooth signal (STDEV)	Variability explained (%)	Original data (STDEV)	Smooth signal (STDEV)	Variability explained (%)	Original data (STDEV)	Smooth signal (STDEV)	Variability explained (%)
BC	90.50	28.50	31.49	0.65	0.34	52.11	0.88	0.59	66.90
BCS	90.25	27.30	30.25	0.39	0.18	45.58	0.91	0.69	75.55
SON	108.95	50.65	46.49	0.61	0.38	62.90	0.48	0.23	47.31
SIN	162.87	74.85	45.95	0.52	0.27	51.99	0.50	0.25	50.95
NAY	189.61	39.94	21.06	0.58	0.40	69.13	0.78	0.48	61.12
JAL	182.30	84.19	46.18	0.46	0.27	58.21	0.57	0.38	67.00
COL	277.89	164.09	59.05	0.48	0.27	55.42	0.82	0.60	73.42
MICH	151.40	62.53	41.30	0.78	0.29	37.63	0.99	0.61	61.84
GRO	171.61	80.81	47.09	0.55	0.31	56.48	0.65	0.26	40.39
OAX	296.98	125.36	42.21	0.75	0.41	54.68	1.09	0.80	73.57
CHIS	294.69	121.98	41.39	0.37	0.17	45.73	0.53	0.36	67.84
TAM	157.45	49.50	31.44	0.50	0.20	40.38	0.54	0.27	49.27
VER	211.14	87.57	41.48	0.57	0.33	57.39	0.44	0.27	61.86
TAB	319.29	53.88	16.88	0.73	0.45	61.50	0.42	0.16	37.43
CAM	176.24	94.62	53.68	0.45	0.24	54.15	0.64	0.50	78.10
YUC	172.52	73.56	42.64	0.46	0.18	39.09	0.44	0.21	47.29
QROO	201.50	80.19	39.80	0.33	0.11	34.32	0.81	0.59	72.03
Average			39.91			51.57			60.70

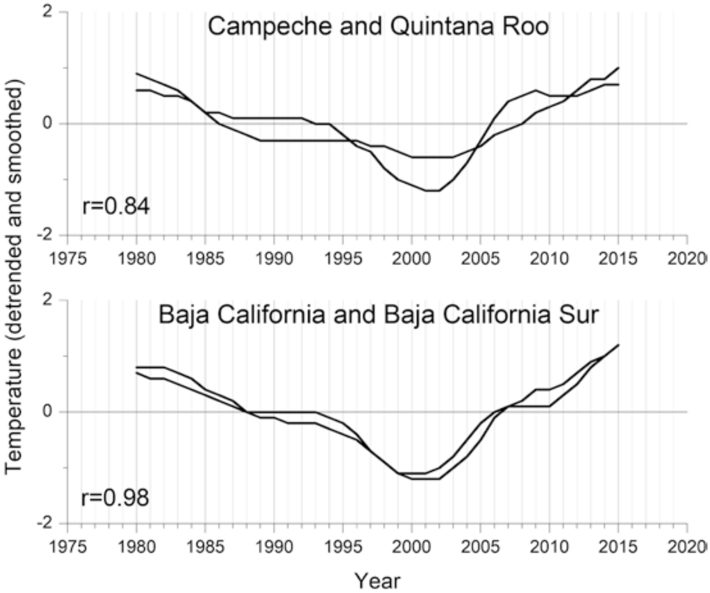

Fig. 15.11 Maximum correlations between minimum temperatures (low-frequency signals) among West coast states BC and BCS (bottom) and East coast states CAM and QROO (top)

the relationships between the variables. For the AMO, the highest positive correlation was found with the maximum temperature in TAM ($r = 0.97$) and the highest negative correlation also with the maximum temperature but, in CAM ($r = -0.88$), both states in the East coast. For the other two modes of climate variability, the correlation coefficients go from $r = 0.80$ to $r = -0.77$ (NAO) and $r = 0.80$ to $r = -0.50$ (PDO). Figure 15.12 shows the decadal behavior of these variables.

In general, the results show that when the AMO is in a positive (negative) phase, the rainfall in the Mexican coastal states decreases (increases), the maximum temperature increases (decreases), and the minimum temperature decreases (increases). In the case of the PDO, it is observed that when it is in a positive phase, there are increases in temperature (maximum and minimum) in several coastal states. For the NAO, it is not possible to establish generalizations of this type, and its influence depends on the location, extension and morpology of the coastal states. Table 15.3 summarizes the results found in this section.

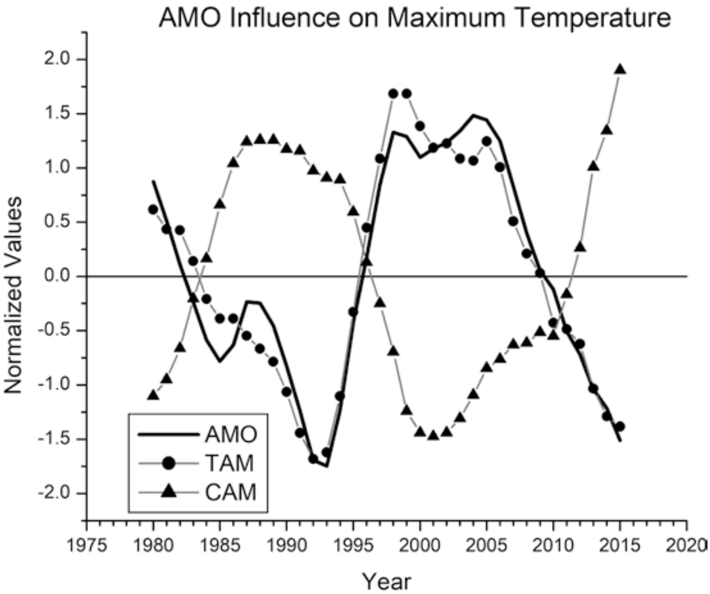

Fig. 15.12 Maximum correlations between decadal variables in two coastal states. The figure shows the long-term behavior of AMO (continuous line) and the maximum temperature in Tamaulipas (circle) and Campeche (triangle)

Table 15.3 Number of significant correlations ($p < 0.05$) founded between climate variables (CV): rain, maximum temperature (TMAX), minimum temperature (Tmin), and global signals (GS) – AMO, NAO, and PDO

	Yearly values				Decadal values			
	Rain	TMAX	Tmin	Total by GS	Rain	TMAX	Tmin	Total by GS
AMO	6	8	9	23	11	12	12	35
NAO	6	1	0	7	10	5	6	21
PDO	4	4	2	10	6	3	7	16
Total by CV	16	13	11	40	27	20	25	72

15.3.4 The Impact of Decadal Climate Variability on Biodiversity- and Natural Resource-Based Economic Activities

Up to this point, the results have shown – through correlation analysis – the influence exerted by the different climatic variability modes (AMO, NAO, PDO) on climatic variables (rain, TMAX, Tmin) in temporal scales of the order of decades. In this section we explore the impact of these variables on biodiversity and different economic activities that occur in the coastal zone and that are based on the exploitation of natural resources over large portions of the territory.

Table 15.4 Maximum correlations (positive and negative) found between decadal climate variables and total production or agricultural products in each coastal state

Coastal state	Maximum significant positive correlation	Maximum significant negative correlation
BC	Tmin and strawberry $r = 0.93$	Tmin and tomatoes $r = -0.88$
BCS	Tmin and potatoes $r = 0.96$	TMAX and total production $r = -0.86$
SON	Tmin and total production $r = 0.70$	TMAX and total production $r = -0.86$
SIN	AMO and total production $r = 0.69$	Tmin and total production $r = -0.69$
NAY	AMO and mango r = 0.84	NAO and total production $r = -0.75$
JAL	Tmin and total production $r = 0.87$	TMAX and total production $r = -0.92$
COL	AMO and lemon $r = 0.87$	Rain and lemon $r = -0.92$
MICH	Tmin and blackberry $r = 0.91$	Rain and avocado $r = -0.61$
GRO	Rain and mango $r = 0.81$	TMAX and total production $r = -0.77$
OAX	Rain and maize $r = 0.81$	Rain and sugarcane $r = -0.85$
CHIS	Rain and total production $r = 0.82$	Tmin and maize $r = -0.65$
TAM	Tmin and total production $r = 0.77$	NAO and sorghum $r = -0.76$
VER	Rain and orange $r = 0.72$	Non
TAB	TMAX and cocoa $r = 0.90$	Rain and cocoa $r = -0.67$
CAM	Tmin and maize $r = 0.94$	Rain and soybean $r = -0.83$
YUC	Tmin and lemon $r = 0.63$	TMAX and lemon $r = -0.83$
QROO	NAO and sugarcane $r = 0.58$	TMAX and chili $r = -0.76$

The coastal states of Mexico are the main agricultural, fishing, and livestock producers of the country, being also an important source of forest resources of economic importance. Due to the prevailing climate in the country, economic conditions, and access to agricultural technology, in 13 of the 17 coastal states, most of the crops are carried out in the open with rain-fed farming systems. For these 13 states, on average, 84% of the planting area is exposed to climatic conditions. On the other hand, in the Mexican northwest states (BC, BCS, SON, SIN), only 12% of the surface is exposed.

The results associated with the influence of climatic variability of the order of decades on agricultural productivity showed (a) the most influential mode of climate variability was the AMO (67.7% significant correlations) followed by the NAO (51.5% significant correlations) and the less important was the PDO with only 17.6% of significant correlations and (b) the rain and maximum temperature presented significant correlations in 64.7% of the studied cases and the minimum temperature in 58.8%. Table 15.4 shows the most important relationships among agricultural products and climate variables for each coastal state.

As an example of the temporal behavior of some of the variables described, Fig. 15.13 shows the long-term (decadal) structure of lemon production in Colima (COL) and cocoa in Tabasco (TAB) with several low-frequency climate variables and modes of climate variability.

Similar influences could be observed in low-mobility fishery products like octopus catches and oyster and clam production in several states (Azuz 2012).

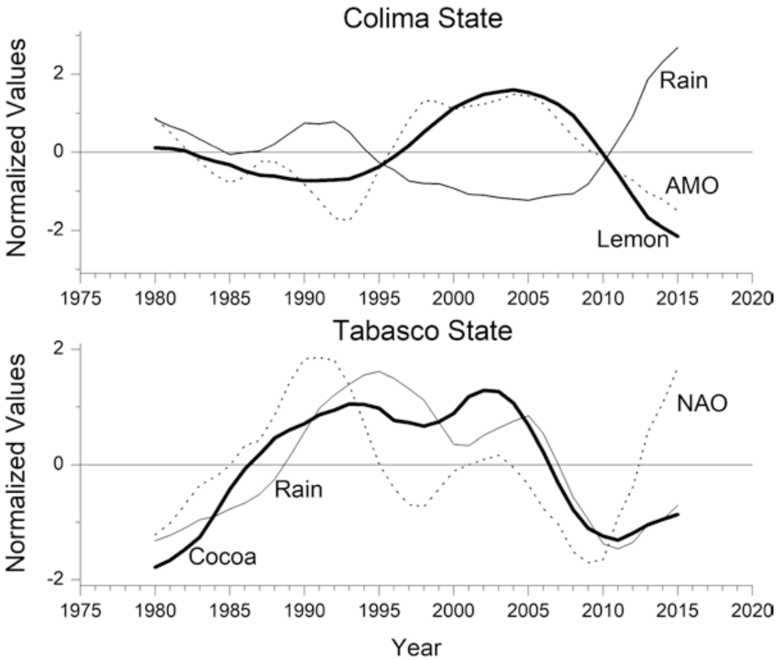

Fig. 15.13 Long-term (decadal) behavior of (**a**) lemon production in COL (bold line) and the influence of AMO (dotted line) and rain (continuous line) on it (top) and (**b**) cocoa production in TAB (bold line) and the influence of NAO (dotted line) and rain (continuous line) on it (bottom)

About 40% of the country's timber forest products come from the coastal states. The three most important states in terms of their production are JAL, MICH, and OAX and represent 26% of the national total. For the analysis of these variables, the available information only covers the period 1990–2012. Even with this limited amount of data, the decadal analysis showed the influence of AMO and rainfall on the forest production of these states, particularly the behavior of Oaxaca (OAX) which is shown in Fig. 15.14.

At this point, the central question of this research arises: if the climatic variability and the modes of climatic variability have a clear decadal influence on the different productive activities that take place in the coastal states of Mexico, what will be its influence on the regional biodiversity? The lack of simultaneous measurements between the climatic variables reviewed and the counts related to the quantity and distribution of biological diversity (plants and animals) makes it difficult to perform analyses similar to those presented so far.

In this sense, some observations that could be made would be the following:

(a) Using information from 2005 to 2010 and 2015 (Valderrama-Landeros et al. 2017), the mangrove extension in ten coastal states increases 7971 ha and decreased 6551 ha in six coastal states; in most of these six states, there was a significant growth in the tourist offer during this period, with the changes associated with the use of land for hotel developments.

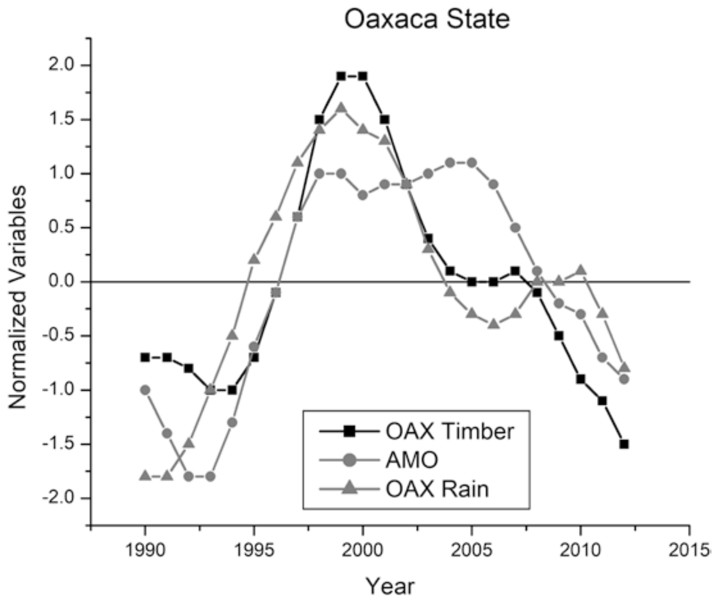

Fig. 15.14 Decadal behavior of wood forest resources in Oaxaca (OAX) state and the influence on it of AMO ($r = 0.78$) and precipitation ($r = 0.82$)

(b) During the period 1993–2011, around 5 million ha of natural vegetation was lost in 16 of the 17 coastal states of Mexico; only Nayarit recovers a small amount of 35,000 ha (see Fig. 15.15).
(c) When the analysis of vegetation loss is carried out strictly in the coastal municipalities, it is observed that of the 152 municipalities considered, 129 experienced loss of vegetation cover (approximately 2 million hectares) which represents 40% of the total loss.
(d) Between 2002 and 2010, the number of endangered species increases from 367 to 475, as well threatened species which goes from 846 to 896 (CONABIO-SEMARNAT 2009; CONABIO 2014).

Considering the top ten municipalities with the greatest loss of vegetation cover during the period 1993–2011, nine are located in four coastal states of the northwest part of the country: Baja California (2), Baja California Sur (1), Sonora (4), and Sinaloa (2). For these nine municipalities, the total loss of vegetation cover surface was 876,899 ha. It is interesting to note that for the analyzed period 1993–2011, all the coastal states considered had a minimum rainfall and minimum temperatures (decadal series) around the year 2000, which is consistent with a relative minimum in the PDO signal in the same period. Between 1995 and 2005 in these states, a negative phase of rain and minimum temperature was observed, which could have been the cause of the loss of natural vegetation. The highest observed correlation is presented in Fig. 15.16.

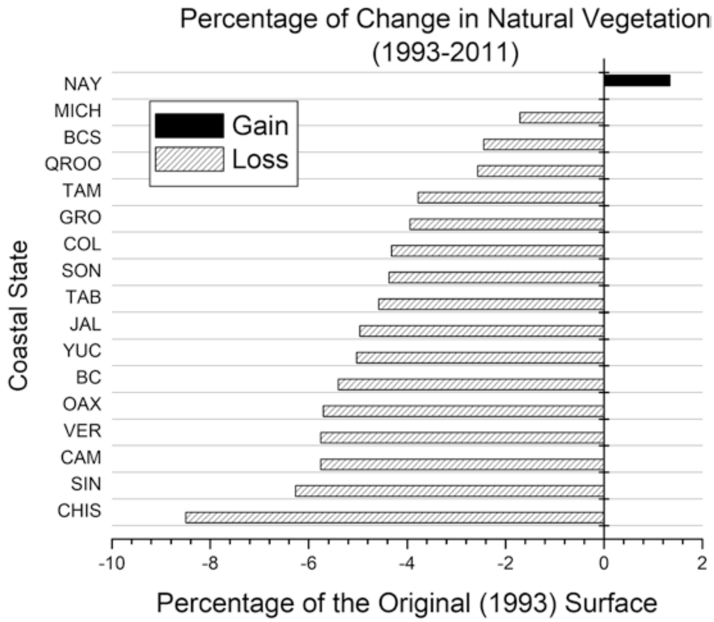

Fig. 15.15 Changes in natural vegetation observed in the Mexican coastal states during the period 1993–2011

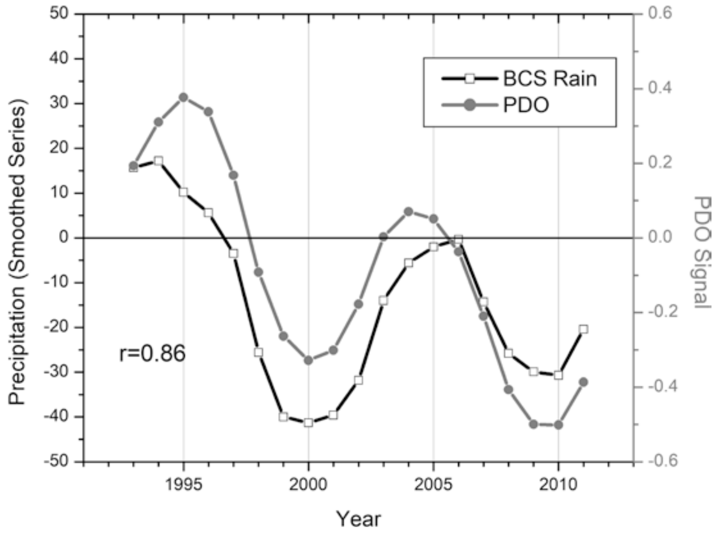

Fig. 15.16 Long-term behavior of rain in BCS (gray line) and PDO (black line) for the period 1993–2011

15.4 Discussion and Conclusions

The marked increase in rainfall and minimum temperature observed in yearly time series across the majority of Mexican coastal states could impact the abundance, the local and regional distribution of biodiversity, as well the functions and health of several ecosystems. The increase in minimum atmospheric temperatures is a verifiable fact for the Mexican coastal states. Its impact on natural vegetation, crops of commercial value, microorganisms, and pests can produce significant alterations of plant diversity and, as a result, on the distribution of animal species.

Weather, climate, climate variability, and climate change could impact biodiversity, agriculture, forestry, and fishery in Mexican coastal states in several time scales. The decadal analysis performed on the data has shown that the low-frequency part of the different climatic variables studied can be as important as the annual variability. The capacity of response and adaptation of plants and animals to the long-term changes associated with climate variability and climate change will be a fundamental factor for the preservation of coastal biodiversity (Mantua et al. 1997; Vázquez-Hurtado et al. 2011; Salvadeo et al. 2013; Bay et al. 2018). In addition to biodiversity, climate variability has a strong influence on food security (Zhao et al. 2005; Ray et al. 2015); its influence on agriculture production has been demonstrated from the correlation analysis carried out between the climatic variables, the modes of climatic variability, and the specific products of the coastal states.

Although the periodic elaboration of inventories of flora and fauna is a costly exercise for countries with large territorial extensions such as Mexico, it needs to establish with certainty the long-term influence exerted by climatic variables and modes of climatic variability on biological diversity (i.e., existence, genetic characteristics, abundance, health, and distribution). Using information from natural vegetation, limited in time and obtained with long sampling intervals (1993–2011), it was possible to establish the clear influence of some of the modes of climatic variability (e.g., PDO) on rainfall and the minimum temperature of the states where at the municipal level there was the greatest loss of vegetation cover. The specific mechanisms through which these planetary signals (modes of climatic variability) influence, at least, the existence and distribution of natural plant species are currently an active and open research area at the international level, as well as the measures of conservation that consider climate change and variability (Langlais et al. 2017; Wessely et al. 2017).

With the existing information, it is possible to suppose that the different global signals present in the northern hemisphere (AMO, NAO, PDO) will play a key role at least in the geographical distribution of the plant and animal species present in Mexico. Additionally, it has been shown how these modes of climatic variability already have an important effect on rain and temperature patterns, which in turn can be mechanisms that trigger changes in the characteristics of the country's biodiversity through the existence and distribution of nutrients, prevalence of heat and cold waves in scales of decades, control in the appearance and location of pests, and abundance and characteristics of microorganisms, among other factors.

Finally, it is important to mention that this study proves the existence of long-term changes that are manifested on a regional scale in Mexico (coastal states) at least in the climatic variables studied (rainfall and atmospheric temperatures) and that these changes can be induced by the behavior of the modes of climatic variability analyzed (AMO, NAO, PDO). In this sense, it is important to mention that the research groups and research centers should consider at the same level of importance the impact of extreme weather events, climate change, and climatic variability of the order of decades on Mexican biodiversity.

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Chapter 16
Development of Electrical Infrastructure and Biodiversity Conservation in Mexico

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Abstract The development of electrical infrastructure can affect the biodiversity, but it is possible to avoid or minimize the major impacts resulting from the construction and operation of new facilities like power plants, electric transmission lines, or fuel supply systems. Until 2014, the National Power Company of Mexico (Comisión Federal de Electricidad (CFE)) was responsible for developing new electrical infrastructure and, since the decade of 1970, has implemented a number of actions aiming to avoid, mitigate, and compensate the potential impacts caused by new projects. Currently, private companies are entitled to build new facilities, and the experience acquired by the National Power Company on biodiversity conservation is certainly useful for planning and developing these projects.

Therefore, this chapter describes and analyzes some of the most relevant measures or actions taken by CFE for biodiversity conservation and proposes some technical and planning options for developing new projects, which can be useful for improving the environmental performance of new electrical infrastructure.

Keywords Biodiversity conservation · Biodiversity recovery · Impact mitigation · Electricity and biodiversity

16.1 Introduction

Virtually all human activities modify the environment, either by eliminating or fragmenting ecosystems, changing hydrologic or matter flows, or incorporating matter or energy that modifies the quality of soil, water, or air. These modifications have

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repercussions on ecosystems and the services provided by them. Infrastructure development for electricity production and transmission is not the exception, even when considering that the exploitation of renewable energies cataloged as clean does affect ecosystems, either by modifying the sites used to build facilities or due to a direct impact on the biota. Nevertheless, the current situation in Mexico requires a sustained economic development, intended to improve the living conditions of the population; this requires increasing the electrical infrastructure, among others, but with a minimum impact on natural and human-cultural capitals.

For the above, the Federal Power Commission of Mexico (Comisión Federal de Electricidad (CFE)) incorporates strategies to prevent, minimize, and mitigate environmental impacts into project development, which include actions aimed to protecting populations of vulnerable species and preserving ecosystems. The most significant are those intended to prevent or minimize adverse effects on key biotic components, sometimes even exceeding the legal requirements in the matter.

CFE has reviewed and analyzed the environmental implications of its activity with different society stakeholders, especially in academia, in order to improve its performance in this area. A task that should not be postponed is to verify the accuracy of forecasts generated during project impact assessment, as well as the effectiveness of measures or programs to prevent or mitigate the effects thereof on biodiversity.

Now that the electrical industry has opened up to private investment, the experience gathered in relation to maintaining or recovering biodiversity should be reviewed to provide feedback for the forthcoming infrastructure planning and execution in the electrical sector. This revision should also provide support in the analysis of strategies proposed for ecosystem protection with environmental authorities.

16.2 Biodiversity Protection: Legal Framework

In Mexico, Environmental Impact Assessment (EIA) is the main environmental policy instrument to prevent deterioration that may result from the implementation of works and activities (DOF 1988); when a project implies clearing of forest vegetation, a License for Changes of Land Use in Forest Land should also be obtained (DOF 2003). Both instruments assess the potential effects of projects or activities on environmental biotic components.

Various authors and international organizations consider that EIA is a tool to identify, during the early stages of project development, the potential environmental, social, and economic impacts, as well as to explore strategies to reduce these impacts. This information sets the basis to adapt project designs to the particular environmental requirements in order to submit projections and recommend options for decision-makers. Within this context, the EIA may anticipate environmental and economic benefits by reducing environmental impacts but also by decreasing the time required for project design and implementation and avoid costs related to environmental impact management (Convention on Biological Diversity 2017).

In Mexico, however, according to the definition of EIA in Article 28 of the General Law on Ecological Equilibrium and Environmental Protection (*Ley General del Equilibrio Ecológico y la Protección al Ambiente,* LGEEPA; DOF 1988), the government plays a key role. EIA is established as the procedure *through which the Secretariat sets forth the conditions for conducting works and activities that may lead to ecological imbalance or exceed the limits and conditions set forth in the applicable provisions to protect the environment and preserve and restore ecosystems in order to prevent or minimize the respective negative environmental effects.* To obtain the respective authorization, an environmental impact statement (EIS) should be submitted as per Article 30 of LGEEPA and Articles 11 and 12 of the Ordinance in Environmental Impact Matters (DOF 1988, 2000).

A change of land use in forest areas is *the total or partial clearing of forest vegetation in order to use land for non-forestry activities* (*Article 7 of* the General Law for Sustainable Forest Development – *Ley General para el Desarrollo Forestal Sustentable*). This can only be authorized as an exception when *there is evidence that biodiversity is not compromised; that no soil erosion, deterioration of water quality*, *or reduction in catchment area will occur; and that the proposed land use is expected to be more productive in the long term* (DOF 2003, 2005). A technical study (ETJ, for its acronym in Spanish) should be submitted to obtain approval.

In order to ensure regulatory compliance, but especially in order to warrant that projects adequately incorporate environmental considerations and avoid damaging the integrity of socio-ecosystems, CFE also incorporates social and environmental variables into the planning and designing stages of projects, besides submitting the respective EIS and ETJ for regulatory approval.

The requirements related to EIS and ETJ are set forth in the regulations mentioned above. Accordingly, the environmental authorities have issued guidelines for the elaboration of these documents (SEMARNAT 2015a, b, 2017). These analyze the potential impacts of a project on biodiversity and the measures to prevent, minimize, or mitigate any potential adverse effects. These analyses should incorporate temporal variations and the spatial heterogeneity of ecosystem structure and function in order to determine whether the project is likely to affect any trends identified. Additionally, to ensure compliance with prevention and mitigation measures, an environmental follow-up program should be included.

Additional legal requirements for the protection of biodiversity that should be met in project planning and execution are set forth in the General Law on Wildlife and its regulations; management programs for protected natural areas and federal, state, and municipal territorial regulations; as well as Official Mexican Standards dealing with environmental matters. These regulations prohibit carrying out any activities in mangrove areas and establish restrictions to conduct either activities in evergreen mountain cloud forests and tropical rainforests or works that may endanger populations of protected species, especially in the case of mammals and marine turtles and birds of the family Psittacidae.

Although these guidelines are consistent with the core objectives of protected natural areas, often times, these fail to consider social needs. In most of these areas, management programs restrain or prevent both infrastructure development and other productive activities, even when projects aim to meet the needs of local populations living within a protected area, as is the case of projects to supply electric power to human settlements.

On the other hand, state and municipal territorial regulations are often drafted with a conservationist approach, without considering that one key objective is to regulate human activities considering the criteria set forth in Article 19, fraction III, of LGEEPA (DOF 1988). This states that *the suitability of every zone or region should be considered according to the local natural resources*, *distribution of human settlements*, *and major economic activities.* Sometimes this situation also complicates providing infrastructure and services required by communities.

16.3 Environmental Impact Assessment at CFE

According to the now abrogated Law on Public Energy Services (*Ley del Servicio Público de Energía*), until 2014 CFE was responsible for *producing*, *conducting*, *transforming*, *distributing*, *and supplying electric power intended for providing a public service.* This includes *I. planning of electric power services at a national level*; *II. electric power production*, *conduction*, *transformation*, *distribution*, *and sales*; *and III. performance of operations*, *facilities*, *and activities that require planning*, *execution*, *operation*, *and maintenance of national electrical power systems* (DOF 1975). These responsibilities were modified on 2014 when the Law on the Electric Power Industry (*Ley de la Industria Eléctrica)* was issued; this sets forth that *the supply of electric power is a service of public interest*. *Accordingly*, *electric power production and marketing services should be provided under a free-competition framework* (DOF 2014).

In Mexico, Environmental Impact Assessment (EIA) was established in 1988 when LGEEPA came into force. However, in the decade of 1970, CFE carried out the earliest environmental impact studies in order to predict the potential effects derived from the operation of the *Laguna Verde* Nuclear Power Plant. In the late 1970s and early 1980s, CFE elaborated the environmental impact analysis of cooling water discharges for Punta Prieta, Manzanillo, and Puerto Libertad power plants (Universidad de Sonora 1980; Zúñiga 2003). On the second half of the decade of 1980, environmental impact analyses supported the modification of the cooling systems of the Tuxpan and Petacalco power plants to prevent or minimize potential adverse effects on the aquatic biota (Zúñiga-Gutiérrez 2003). By the end of the twentieth century, the environmental variable was incorporated into project planning, specifically during the stage of site selection for location of new power plants; subsequently, this was extended to the selection of routes for new transmission lines. During the past three decades, CFE conducted a large number of environmental impact analyses using different methodologies to predict the potential environmental impacts of projects, as well as to define alternatives to prevent, mitigate, and compensate for any negative effects on biodiversity. CFE is currently conducting environmental feasibility studies for specific projects and has drafted Diagnostics on Strategic Environmental Factors for some regions of Mexico. Although with different scopes, both types of studies have as core objective a timely identification and assessment of the potential environmental risks related to electric infrastructure projects (Platas-Hérnandez 2017 Personal communication).

At the beginning of this century, CFE strengthened its collaboration with academic and research institutions in order to (1) assess the potential environmental impact of new projects, (2) provide training on environmental matters to project staff, and (3) analyze the activities conducted in these regards. Between 2003 and 2011, CFE organized five national meetings including an open discussion focused on its social-environmental activities. CFE professionals, nongovernmental organizations, representatives of environmental agencies, as well as scholars and researchers participated in those meetings.

The vision of CFE about social and environmental issues was clearly expressed in a public statement in 2008 by the General Director's office. According to it, the construction of major projects implies removing obstacles and dealing with issues that were not as important in previous years but that may be critical for the success of a given work: environmental care, relationship with social and political stakeholders, and regulatory management (Laris-Alanis 2008). The environmental performance of CFE, which was acknowledged on 2010 by the International Association for Impact Assessment (IAIA), fostered a constructive communication with federal and state environmental agencies.

Until 2014, CFE built or promoted new electricity transmission and production projects in Mexico (with the exception of co-production and self-supply projects); for that reason, it has gained ample experience regarding management of environmental impacts derived from new electrical infrastructure.

16.4 Expansion of Electric Power Services

The Energy Secretariat foresees that power demand will continue to increase, with the consequent significant growth in the electrical power sector. According to the 2005–2029 National Electrical System Development Program (PRODESEN, for its acronym in Spanish) (SENER 2017), in 2016, the installed production capacity was 73,510 MW, with a production of 319,364 GWh and a peak demand on integrated electrical system of 40,893 MW/h. The peak demand is expected to grow at 3.0% per year between 2017 and 2031, thus requiring an installed capacity of 113,269 MW by 2031. This means that the installed capacity would have to increase by nearly 55%, which requires the installation of 487 electricity production facilities within this period.

According to PRODESEN, by 2031, the installed capacity with clean energies will increase to 34,964 MW by building wind, photovoltaic, efficient cogeneration, and nuclear electricity projects. Also considered, although with lower contributions, is the use of bioenergy, geothermal, hydraulic, and thermo-solar projects. On the other hand, a total of 20,876 MW will be installed by using fossil fuels. During the same period, 137 CFE power plants with a total installed capacity of 15,814 MW will be phased out. Sixty-nine percent of this capacity corresponds to thermoelectric plants that use fossil fuels.

Currently, the National Electric System has 102,391 km of lines with voltages ranging from 69 to 400 kV. PRODESEN estimates that 410 projects will be carried out with a total length of 23,772 km of transmission lines during 2017–2029. Additionally, the number of transformation and compensation substations will increase by 256 and 259, respectively, representing a corresponding increased capacity of 58,099 MVAr and 11,930 MVAr.

Given this accelerated growth scenario and in order to improve future decision-making and actions aiming to protect biodiversity, it is convenient to gather and review the experience gained on the incorporation of environmental variables into project planning and execution, as well as advocate measures to mitigate the potential disturbances to environmental biotic components.

16.5 Contribution to Knowledge and Biodiversity Conservation by CFE

In addition to performing specific actions aiming at biodiversity conservation, CFE carries out field studies and desk reviews to support the environmental assessment of projects and define environmental mitigation activities by gaining knowledge on the environmental characteristics of sites where works will be executed. Hence, these projects have contributed to expand our knowledge on biodiversity.

Some of the contributions and actions performed during the past years are the following:

16.5.1 Discovery of New Flora and Fauna Species

In 2001, during field studies for tracing a transmission line in the state of Nuevo León, a cactus species was discovered, naming it *Digitostigma caput-medusae* (Nevárez -de-los-Reyes 2006). Separately, during the field studies for the assessment of a hydroelectric project in the state of Guerrero, a new frog species was found (preliminarly denominated as *Rana papagayo*) (Programa Universitario del Medio Ambiente-UNAM 2004).

16.5.2 Calakmul Bats

Researchers from Colegio de la Frontera Sur, Universidad Nacional Autónoma de México, and the Bat Conservation Program of Mexico performed studies on the effect on bat populations derived from the installation of the Escárcega-Xpujil

Transmission Line (TL) running between the municipalities of Escárcega and Calakmul in the state of Campeche. These studies, in addition to establishing that this TL poses no threat to bats, provided information about the specific composition of the bat community inhabiting the cave known as "Volcán de los Murciélagos" (Bat Volcano) located in the protected natural area known as "Área Sujeta a Conservación Ecológica Balamkú" (Area Subjected to Ecological Conservation) (Arroyo-Cabrales et al. 2011). The relevance of this cave resides in it being home to approximately one million bats belonging to eight species: *Mormoops megalophylla*, *Pteronotus parnellii*, *P. davyi*, *P. personatus*, *Natalus stramineus*, *Myotis keaysi*, *Nyctinomops laticaudatus*, and *Glossophaga soricina.* Caves where there are populations of more than 50,000 bats are scarce, and most of them are located in temperate areas. The study results were recorded in a book that covers not only biological and ecological aspects but also social perceptions about bats, in addition to being a guide for the identification of species found in the Calakmul region; therefore, this document is of interest for both the general public and scholars.

16.5.3 Singing Records of Songbird Species

Studies related to power transmission projects conducted in western Mexico led to the elaboration of a "field guide" to identify songbirds through recordings in multimedia format that allow reproducing the singing of each of these species, in turn allowing to detect its presence without a direct visual observation. A total of 50 species has been documented (Langle-Flores 2006).

16.5.4 Northeast Botanical Garden

In 2006, in order to support the preservation of vegetation in northeastern Mexico, CFE built a botanical garden in the land occupied by "Residencia de Obra de la Zona Metropolitana" (Metropolitan Zone Work Site) located at Monterrey City, which was inaugurated on 29 July. On 04 October 2006, it was registered as a Wildlife Conservation Management Unit under the name "Vivero y Jardín Botánico CFE-Construcción Cactus del Noreste" (CFE Northeastern Cacti Nursery and Botanical Garden). This garden currently includes 130 species characteristic of arid areas, including 100 cacti and 13 agave species (Barba 2017 – Personal communication).

16.5.5 Mangrove Restoration at **Laguna de Términos**

As a measure aimed to offset the disturbance of natural areas caused by the construction of transmission lines in the state of Campeche, 17.5 ha of mangrove was restored at *Laguna de Términos*. The following activities were performed: (1)

detection, evaluation, and preparation of an area susceptible to be restored; the preparation consisted in restoring hydrologic conditions favorable for mangrove by constructing channels; (2) selection, conditioning, and concentration of plantlets and propagules of three mangrove species; (3) reforestation; and (4) maintenance, 5-year follow-up, and evaluation of the reforestation program. For propagule management, an area of 1900 m^2 was conditioned, and more than 41,000 plantlets were collected from nearby areas where conditions allowed controlled extraction. After a 5-year follow-up, a mangrove community had been fully established (León-Burgos 2006, 2008 Personal communication).

According to information reported by Agraz (2017), the restoration program has been so successful that mangroves have continued growing and the associated environmental services increased.

16.5.6 Howler Monkey Relocation

Habitat fragmentation is one of the major threats to biodiversity in Mexico. In the Yucatán Peninsula, there are groups of howler monkeys (*Alouatta pigra*) that survive in small and remote forest patches, with a low survival expectancy in the long term. Under these conditions, an appropriate option to preserve them is to relocate groups of monkeys to areas where forest patches are larger. As a supplementary measure to offset the impacts of the construction of a transmission line in the state of Campeche, seven family groups of howler monkeys that previously inhabited highly fragmented rainforest areas (habitat fragmentation was not caused by the construction of the transmission line) subjected to heavy human pressure were relocated to better-preserved and low-pressure rainforest areas. 27 adults, 5 juveniles, and 8 infants were relocated; 19 were males and 20 females; the sex of 1 infant could not be established. To evaluate the success of this program, the relocated groups, the composition by age, and the behavior of each group were monitored and controlled for 4 years (León-Burgos 2008 Personal communication).

16.5.7 Studies on Otters and Crocodiles at El Cajón Dam

The river otter (*Lontra longicaudis*) and river crocodile (*Crocodylus acutus*) are species protected by Mexican regulations that have a wide distribution range in Mexico; however, they have been seriously affected by human activities. During studies performed before the construction of *El Cajón* Dam across the Santiago River, the presence of both species was recorded in the area that would be occupied by the dam reservoir. Otters were also recorded in secondary affluents. *Instituto de Ecología A. C.* provided follow-up to populations of both species during construction works. Based on recommendations derived from these studies, CFE decided that crocodiles *would be left in the new reservoir, evaluating their survival over 1 year; then, the status of the crocodile population would be analyzed if they were to be relocated outside the dam reservoir or left there onsite in a new area under a management program. Separately, the survival of otters was assessed, and data on the distribution and movement patterns across the new reservoir* were recorded (Instituto de Ecología A.C. 2006a, b).

During the filling of the dam reservoir, the Universidad de Guadalajara evaluated the permanence and distribution of both species. It was observed that crocodiles remained on the sites previously occupied by them over the Santiago River, while otters populated mainly secondary affluents and, to a lesser extent, the main reservoir. Follow-up monitoring after the reservoir filled up showed that otters continued using the tributaries and the main reservoir, whereas crocodiles still remained in the same area of the Santiago River as before the dam construction. Also characterized were crocodile sunbathing spots as well as likely nesting sites (Universidad de Guadalajara 2008).

16.5.8 Mitigation During the Construction of Power Transmission and Transformation Projects

The main impact on biodiversity caused by power transmission lines and electric substations is related to vegetation clearing. During the operation stage, there is a minor impact due to maintenance of surveillance pathways and from pruning of plants that may interfere with the operation and safety of transmission lines. The collision of birds with line cables is observed occasionally. The main actions to mitigate these effects include the rescue of flora and fauna prior to works, soil restoration, and placement of anti-collision systems.

16.5.8.1 Rescue of Flora and Fauna

The rescue of flora and fauna is carried out prior to vegetation clearing, focusing primarily on species that are either protected or of scientific or economic importance. These plants and animals are relocated to areas with environmental conditions that are suitable for survival. Afterward, a follow-up for 5–10 years is provided to plant specimens rescued to increase survival.

An example of the extent of biota rescue programs when the alteration of biodiversity relevant areas is unavoidable includes the actions taken to mitigate the impact of two transmission lines (TLs) located in the Yucatan Peninsula. CFE relocated 15,529 plant specimens belonging to 35 species of families Cicadaceae, Capparaceae, Arecaceae, Zygophyllaceae, Anacardiaceae, and Orchidaceae; 186 animal specimens (45 amphibians, 38 mammals, and 103 reptiles) before constructing the *Escarcega-Potencia/Xpujil* TL; 23,321 plant specimens of families

Cicadaceae, Arecaceae, and Anacardiaceae; 21,844 Orchidaceae; and 107 animal specimens before establishing the *Xpujil-Xulha* TL. Many of the species rescued are protected by law (Universidad de Campeche 2017).

16.5.8.2 Reforestation and Soils Restoration

To compensate for the loss of vegetation, areas are reforested with species that are indigenous to region where works are carried out, besides executing soil restoration activities. Both actions support water infiltration into subsoil. The species, reforestation technique, and soil conditioning process, as well as the monitoring and evaluation program, are selected and designed according to the local conditions (CONAFOR 2010). The aim of reforestation is to reestablish, to the extent possible, the structure and processes of the primary ecosystem; therefore, this is more a restoration or environmental rehabilitation program than a mere reforestation activity.

To compensate for impacts on vegetation derived from the construction of TL's "El Encino II-Cuauhtémoc II" and "San Pedro Potencia Cuadro de Maniobras Cahuisori," in the state of Chihuahua, CFE planted 34,000 oaks and 25,000 pines. The total reforested area was 53 ha, achieving a plant survival rate of around 85% (Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias 2017; Universidad Autónoma de Chapingo 2017).

As part of CFE's environmental commitment, the execution of these activities commonly involves scholars or researchers for evaluating the success of these programs and implementing a systematic approach for the application of the experience gained in future projects. Also the participation of local inhabitants – ultimate owners of these natural resources – is also encouraged, for them to carry out all the long-term conservation actions.

16.5.9 Contribution to the Mexican Forestry Fund

In addition to mitigation and compensation measures that are performed on each project affecting forestry land, CFE provides economic contributions to the Mexican Forestry Fund as established in Article 118 of the General Law for Sustainable Forestry Development (DOF 2003). The objective of environmental compensation for changes of land use in forest land is to generate or recover forest ecosystems to compensate for vegetation clearing and the environmental services that were lost as a result. The National Forestry Commission of Mexico manages these funds. As an example of the magnitude of this contribution, from 2014 to 2017, CFE contributed $121, 269,938.43 Mx pesos (approximately 6.7 million USD) to transmission and transformation projects alone.

16.6 Project Planning and Design

16.6.1 Modification of Cooling Water Discharges from the Tuxpan Power Plant

In 1986, CFE carried out the first project modification to protect an ecosystem, after determining that cooling water from the Tuxpan Thermoelectric Power Plant (Tuxpan PP), that was originally planned to be performed at *Laguna de Tampamachoco*, had to be discharged to the Gulf of Mexico. Modifications were necessary in order to preserve ecosystemic integrity (Zúñiga 2003).

The Tuxpan PP is located on the coast of the state of Veracruz, between the Gulf of Mexico and *Laguna de Tampamachoco*. This site was originally selected to avoid cooling water recirculation by taking it from the Gulf and then discharging it into the lagoon after use, thereby improving the efficiency of power production. The flow discharged would be 60 m^3/s, with a temperature rise of approximately 8 °C above natural seawater temperature. Discharge water salinity would remain as in natural seawater.

Figure 16.1 compares the natural behavior of salinity for *Laguna de Tampamachoco* versus the expected behavior if cooling water were to be discharged into it. Figures 16.2 and 16.3 show the relationship between substrate attachment of oyster larvae (*Crassostrea virginica*) and natural variations in salinity. Figures 16.4 and 16.5 compare the tolerance to temperature increases for *C. virginica*, estimated through laboratory bioassays, between natural temperatures in the lagoon and those expected in the lagoon cooling water discharge.

Based on this information, it was concluded that cooling water discharges into *Laguna de Tampamachoco* would have transformed this estuarine environment into an ecosystem with marine characteristics, thus affecting the presence and abundance

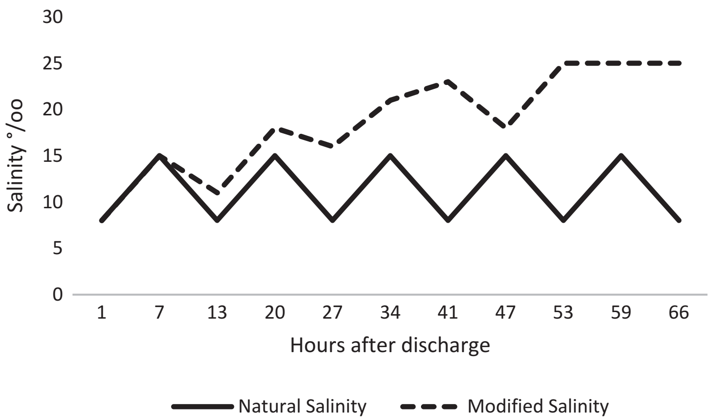

Fig. 16.1 Natural and modified daily salinity pattern of the *Laguna de Tampamachoco*. (Modified from Zúñiga-Gutiérrez 2003)

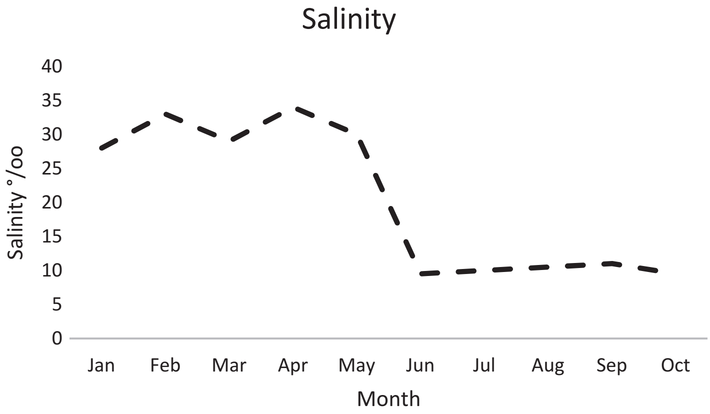

Fig. 16.2 Salinity pattern in the *Laguna de Tampamachoco*. (Modified from Zúñiga-Gutiérrez 2003)

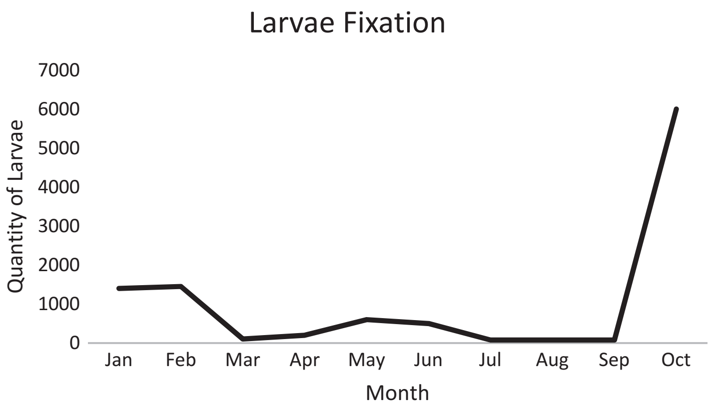

Fig. 16.3 Larvae fixation of oyster along the year. (Modified from Zúñiga-Gutiérrez 2003)

of both resident and migratory species; oysters would disappear as a result of the disruption of larval attachment. Thermal increase would affect most of lagoon biota. These environmental changes would in turn have negatively affected the livelihood of the local human population.

For the above reasons, it was decided to discharge cooling water directly into the Gulf of Mexico despite this involved higher construction and operational costs (since longer channels and higher capacity pumps would be required), thus increasing power consumption, but specially because cooling water would be recirculated during part of the year.

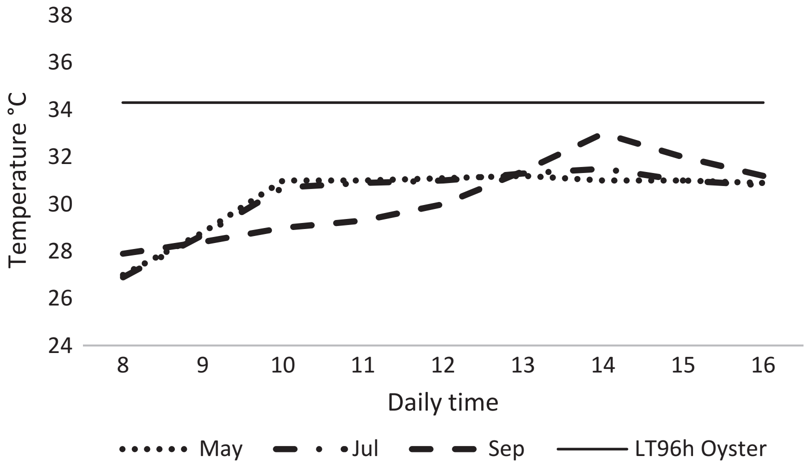

Fig. 16.4 Natural daily thermal pattern in *Laguna de Tampamachoco* compared with half-lethal temperature for 96-h exposure of oyster. (Modified from Zúñiga-Gutiérrez 2003)

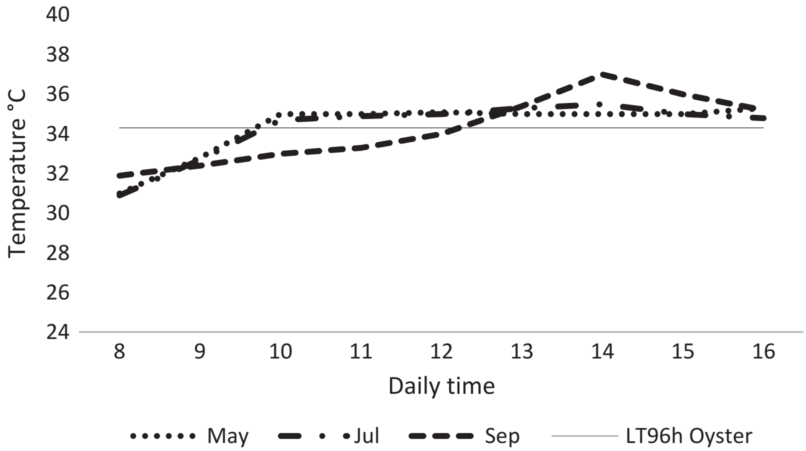

Fig. 16.5 Modified daily thermal pattern in *Laguna de Tampamachoco* compared with half-lethal temperature for 96-h exposure of oyster. (Modified from Zúñiga-Gutiérrez 2003)

16.6.2 Gas Pipeline Trajectories Assessment

In 1997 and in considering alternative routes for two sections of the Cd. PEMEX-Mérida-Valladolid gas pipeline located in the states of Campeche and Yucatán, the impact on biodiversity and population risk indexes were calculated. Both gas pipeline sections ran across forest areas that were well preserved, as well as through some settlements that could be affected by construction works. For the ecological

Table 16.1 Ecological assessment of original and alternative routes for the section running from 18 de Marzo to Santa María Xbacab (Reproduced from Zúñiga-Gutiérrez et al. 2002)

Types of vegetation or land use	HIV_i importance value of habitat i	Original route		Alternative route	
		Length (km)	REI	Length (km)	REI
Protected natural area	10	0	0	4	40
Tropical forest	8	18	164	19	155
Secondary tropical forest	6	11	66	12	74
Agricultural land	4	0	0	5	18
Grassland	2	21	41	26	52
Inhabited	0	0	0	5	0
Total		50	**EII 251**	71	**EII 339**

Difference EII 89.3 (35.67%)

REI ecological relative importance of the habitat, *EII* index of ecological impact of the route

assessment of alternative routes, a group of experts assigned quantitative hierarchies to the different land-use classes or habitats crossed along both trajectories, considering biological diversity, and conservation and protection statuses. An importance value was assigned to each habitat, with 10 as the most ecologically important. The importance value for the subsequent entity was in turn assigned according to the relative importance of each habitat when compared to the most important one. Importance values were multiplied by route length to calculate a relative ecological importance (REI) index. The ecological impact index (EII) for each route was obtained by adding up REI values for each habitat. Table 16.1 shows the results of the assessment of alternative routes for sections located in the state of Campeche (Zúñiga-Gutiérrez et al. 2002). The environmental secretariat approved the construction of the CD. Pemex-Mérida-Valladolid gas pipeline, after considering the routes that represented the lower potential impact on biodiversity.

16.6.3 Manzanillo's Liquefied Natural Gas Terminal and Mangrove Recovery at Laguna de Cuyutlán

Laguna de Cuyutlán, located southeast of Manzanillo, in the state of Colima, comprises four basins. It was modified by man since the late nineteenth century to allow communication with the sea and achieve a hydrodynamic condition that could not be achieved otherwise, since natural communications with the sea had been lost since that time. First, a tunnel was built connecting the lagoon with Manzanillo's bay; subsequently, more than 40 years ago, the *Ventanas* channel was dredged in basin I to ensure cooling water supply for Manzanillo's power plant. Then, in order to increase the flow of seawater and promote water circulation in the lagoon, the *Tepalcates* channel was built in basin II, although it was clogged recurrently by sediment deposits. Water circulation is currently maintained to an important extent due to water suction performed by the Manzanillo CT, a situation that makes water flow from the lagoon center (basin II) to the west (basin I). During the past decades, the lagoon surface area and depth have been decreasing due to a high sediment deposition rate. The Manzanillo Liquefied Natural Gas Terminal (MLNGT) was built within this water body (Universidad de Colima 2006).

Before building the MLNGT, the lagoon had 460 ha covered by mangrove, dominated by *Laguncularia racemosa* followed by *Rhizophora mangle*. The first species prevailed due to the fact that the development of *R. mangle* was limited by low water circulation, attaining peak development in areas influenced by tides. On the other hand, *L. racemosa* grows better in areas with a lower influence of tides.

It is worth stressing that both mangrove species had been displaced from a large portion of the lagoon by *Batis maritima* and other halophyte species; from 1990 to 2003, 152.46 ha of mangrove were lost, equivalent to an annual loss rate of 1.87%. For this reason, recovering the lagoon hydrodynamics was key to reverse this trend in mangrove loss. For this reason, in order to improve the exchange of water between the sea and the lagoon, it was decided to open the navigation canal where the Tepalcates channel was located. In turn, this would increase the abundance of *R. mangle* as well as the coverage, strength, height, and density of *L. racemosa*, as a result of the greater hydrodynamics and influence of tides (Universidad de Colima 2006).

However, despite the projections indicating that the MLNGT would be favorable for the mangrove, its approval was suspended in 2007 due to the enactment of Article 60-ter of the General Law on Wildlife (DOF 2007), which prohibits any activities that may potentially affect mangroves; the construction of MLNGT involved the clearing of less than 1 ha of mangrove vegetation. This situation was solved through the CFE's commitment that mangrove areas would not be permanently occupied to build the dock and that clearing of mangrove plants that could interfere with the project construction would be temporary and these would be reincorporated to their original area once the construction was completed.

Additionally, due to the poor understanding of the hydrodynamic processes that govern the distribution and survival of mangroves, the authority requested the implementation of a mangrove reforestation program as of start-up of construction activities, despite the fact that hydrodynamic conditions were unsuitable for repopulating some mangrove areas. These conditions would be produced with the construction of the navigation channel.

According to the monitoring carried out by CFE, once the navigation channel was opened, the recovery of mangrove areas took place as foreseen in the environmental impact statement of MLNGT (Universidad de Colima 2006). Figure 16.6 shows a strip of mangrove before the opening of the channel (September 2009), evidencing how this vegetation is dry. In March 2013, as shown in Fig. 16.7, once the channel opened up, the same strip appears green.

Fig. 16.6 Mangrove conditions before opening the navigation channel

Fig. 16.7 Mangrove conditions after opening the navigation channel

16.6.4 Ecological Flow and Conservation of Social Ecosystems

The integrity of fluvial ecosystems depends on the amount and seasonality of the water that flows through a river basin; this flow regime determines the structure and function of aquatic and riparian ecosystems (Poff et al. 2009) since it is correlated with key river physical and chemical characteristics, such as water temperature, channel geomorphology, and habitat diversity. It is a key driver of the distribution and abundance of fluvial species that thus regulates the ecological integrity of fluvial systems (Poff et al. 1997). In order to protect the biodiversity of freshwater ecosystems and preserve the assets and services these provide when hydraulic exploitation takes place, the new flow regime should be similar to the natural one, considering the magnitude, frequency, duration, variability, and predictability of flow events (e.g., floods/droughts) as well as the sequence of these conditions (Arthington et al. 2006). If the new flow regime meets these conditions, it is denominated as an ecological flow.

From a social point of view, however, a flow regime is considered as ecological if it generates a structure and functionality of environmental systems that contributes to maintain the assets and services required by society, such as habitat conservation or recovery and water supply for agriculture, aquaculture, and human consumption. For this reason, defining an environmentally acceptable and socially accepted flow requires in-depth analysis and evaluation of the available scientific information with stakeholders to estimate the response of socio-ecosystems to changes in the hydrological regime of a river.

The information on hydrological, hydraulic, climatic, geological, and other areas is still scarce. This leads to uncertainty when projections are made on the response of ecosystems to a flow defined as ecological; therefore, when this flow is implemented, follow-up must be given to the responses of systems, and any adjustments deemed necessary should be made to achieve the flow-related goals previously defined (Gómez-Balandra 2017 Personal communication).

One of the approaches used to reduce uncertainty when predicting environmental impacts derived from human projects or activities is the comparative analysis of the alternatives to carry out the project. This allows an objective setting of the option(s) that represent the lowest environmental impact (Magness 1984) or the alternative that results in the social-environmental conditions that best match the intended scenario. In theory, the option that maximizes the achievement of social needs with the lowest impact on ecosystems should be favored. A flow regime that maintains the integrity of ecosystems is preferred when there is an agreement that the priority is biodiversity preservation or recovery.

The proper evaluation of alternatives requires (1) a systemic approach that allows understanding the changes that will take place in ecosystem structure and process, (2) a systematic conduct, and (3) a quantitative assessment. This approach will allow reducing the uncertainty resulting from the lack of physical and biological information and should be used for establishing an ecological flow.

The Mexican government has issued a standard that sets forth the procedures to determine the ecological flow of a basin or river (Secretaría de Economía 2012). This standard includes two elements that, according to some authors, should be analyzed: (i) enable broader social participation to increase the likelihood of leading to social agreement, especially with sectors that use water resources, and (ii) consider the potential alternatives for water use, especially when more than one type of water exploitation is contemplated.

Any large-scale exploitation of water resources is planned – for example, a large dam, either for drinking water supply, irrigation, or power production, requires an in-depth analysis of the hydrologic flow that should be maintained downstream of the dam, to meet the needs of human population while preserving the desirable ecosystem services and assets. For hydroelectric power plants, which do not consume water, CFE has established two key aspects for the construction of future projects. These will allow maintaining a socially and environmentally acceptable flow regime:

(i) *Adjustment of the operational regime to maintain the seasonal flow variability, establishing a number of operation hours so that generation units release a quantity of water during the day that is of a similar magnitude to the natural flow every month of the year. This operational regime intends to achieve a point that maximizes the power production benefits while maintaining the integrity of relevant ecosystems as well as contributing to meet the social demand for water.*
(ii) *Since the production of energy in a hydroelectric power plant in Mexico is usually concentrated in a few hours a day, a smaller dam is built downstream of the power plant to regulate or distribute the water discharged throughout the day.*

It is important to point out that practically no dam has sufficient capacity to contain the water volumes that are received during extraordinary flows; consequently, the flooding regime downstream the dam remains virtually unchanged. In addition, limiting the height of the dam curtain to reduce its storage capacity ensures maintaining the flood regime.

To maintain the minimum water flow in the river during the dry season, besides limiting the daily operation time of the hydroelectric plant, a portion of the water discharged from the power plant could be used for irrigation or human consumption.

To compare the response of ecosystems to the different operating regimes that can be used in a hydroelectric plant, CFE uses mathematical models to estimate the physical response of water bodies and flood zones downstream the dam when subjected to the hydrological regimes that would be generated by each of the operating schemes. These models correlate the flows registered in hydrometric stations located along rivers with the levels and extension of the water bodies observed in high-resolution satellite images (Universidad de Guadalajara and Comisión Federal de Electricidad 2014).

Although these simulations are not sufficient to evaluate the effects on ecosystems, they are tools that allow comparing the extent of the expected physical change

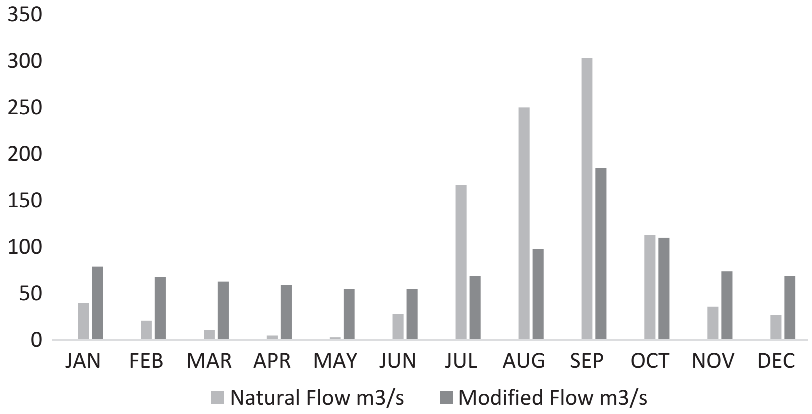

Fig. 16.8 Comparison of natural hydrological regime vs hydrological regime caused by operation alternative 1. (Modified from Universidad de Guadalajara and Comisión Federal de Electricidad 2014)

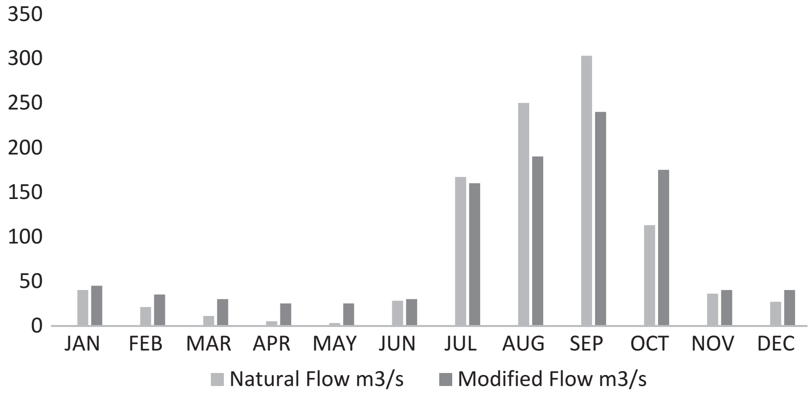

Fig. 16.9 Comparison of natural hydrological regime vs hydrological regime caused by operation alternative 2. (Modified from Universidad de Guadalajara and Comisión Federal de Electricidad 2014)

in water bodies and the flood zones caused by each operation alternative proposed for the hydroelectric power plant. A holistic evaluation requires determining how the physical changes affect water quality, hydraulic conditions, and sediment transport, among others, to evaluate how these modifications may affect the biotic components.

Figures 16.8, 16.9, and 16.10 show the natural flow regime of a river that runs to the Pacific ocean relative to flow regimes generated by three different operation regimes in a hydroelectric power plant that could be built on the river. The first operation regime (Fig. 16.8) maximizes the financial benefits but disrupts river flow seasonality, as the drought and flood pattern disappears, which could radically modify the characteristics of downstream freshwater habitats.

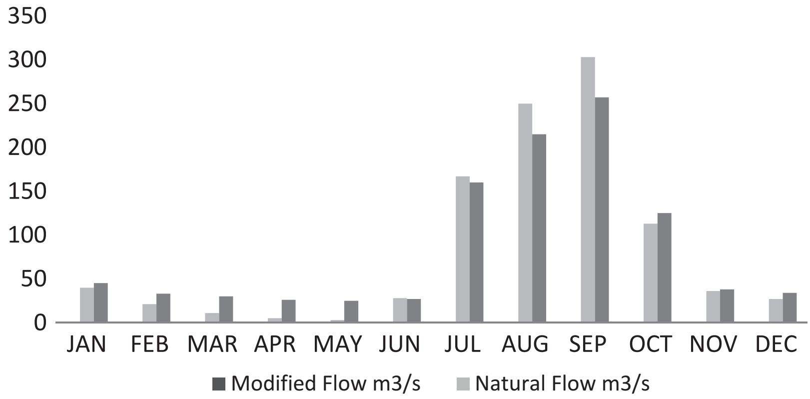

Fig. 16.10 Comparison of natural hydrological regime vs hydrological regime caused by operation alternative 3. (Modified from Universidad de Guadalajara and Comisión Federal de Electricidad 2014)

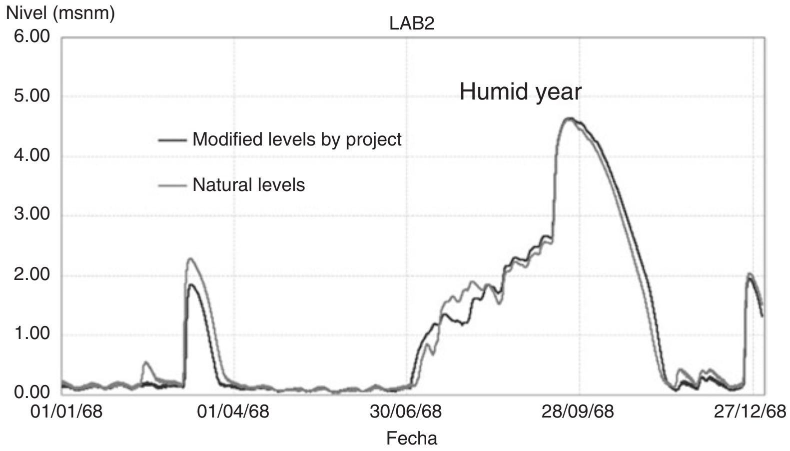

Fig. 16.11 Level of coastal lagoons along humid year. (Modified from Universidad de Guadalajara and Comisión Federal de Electricidad 2014)

The modified flow regimes shown in Figs. 16.8 and 16.9 would result from operation alternatives considered financially feasible (although less profitable than alternative 1) but that produce a flow regime more similar to the natural one, especially in the second of these scenarios. In order to estimate the response of the socio-ecosystems, the model described was applied to (i) coastal lagoons, due to their biological and fishing importance, and (ii) floodplains, because these are relevant agricultural areas.

The annual levels of coastal lagoons and the extension of flooded areas were simulated for several years, which were classified as extremely dry, dry, fair, humid and extremely humid based on runoff volume in the river. Figures 16.11 and 16.12 show,

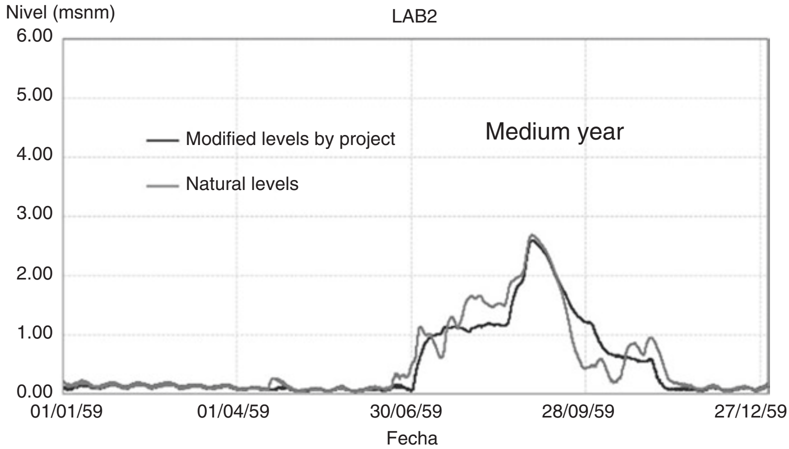

Fig. 16.12 Level of coastal lagoons along medium year. (Modified from Universidad de Guadalajara and Comisión Federal de Electricidad 2014)

for humid and intermediate years, the expected water levels in coastal lagoons if the third operation alternative is applied in the power plant; Fig. 16.13 shows the maximum expected area of lagoons and flooded areas.

Mathematical simulations allow making objective comparisons of the physical response of lagoons and flooded zones when the power plant operates under different regimes. This information may be useful for assessing the potential impacts on aquatic communities and economic activities directly related to the water resource, such as fishing, aquaculture, and agriculture. These models may determine the impacts on other water bodies like rivers or channels, as well as the flooding of household and farming areas. Also, models could be used for assessing any particular use(s) of water.

Simulation results can be used as basis for analyses and discussions with stakeholders regarding water use alternatives, since the ecosystems response can be displayed graphically.

16.6.5 Criteria for Site and Route Selection

Until the decade of 1980, the process for choosing the location of electric infrastructure projects was based on finding the cheapest option, considering both investment and operation costs. Almost three decades ago, that approach started to shift because of an increased environmental awareness within CFE as well as the issuance of stricter environmental laws and a growing social demand to protect the environment (Cancino-Aguilar 2015). As a result, measures to avoid or reduce environmental impacts were incorporated to the different project stages.

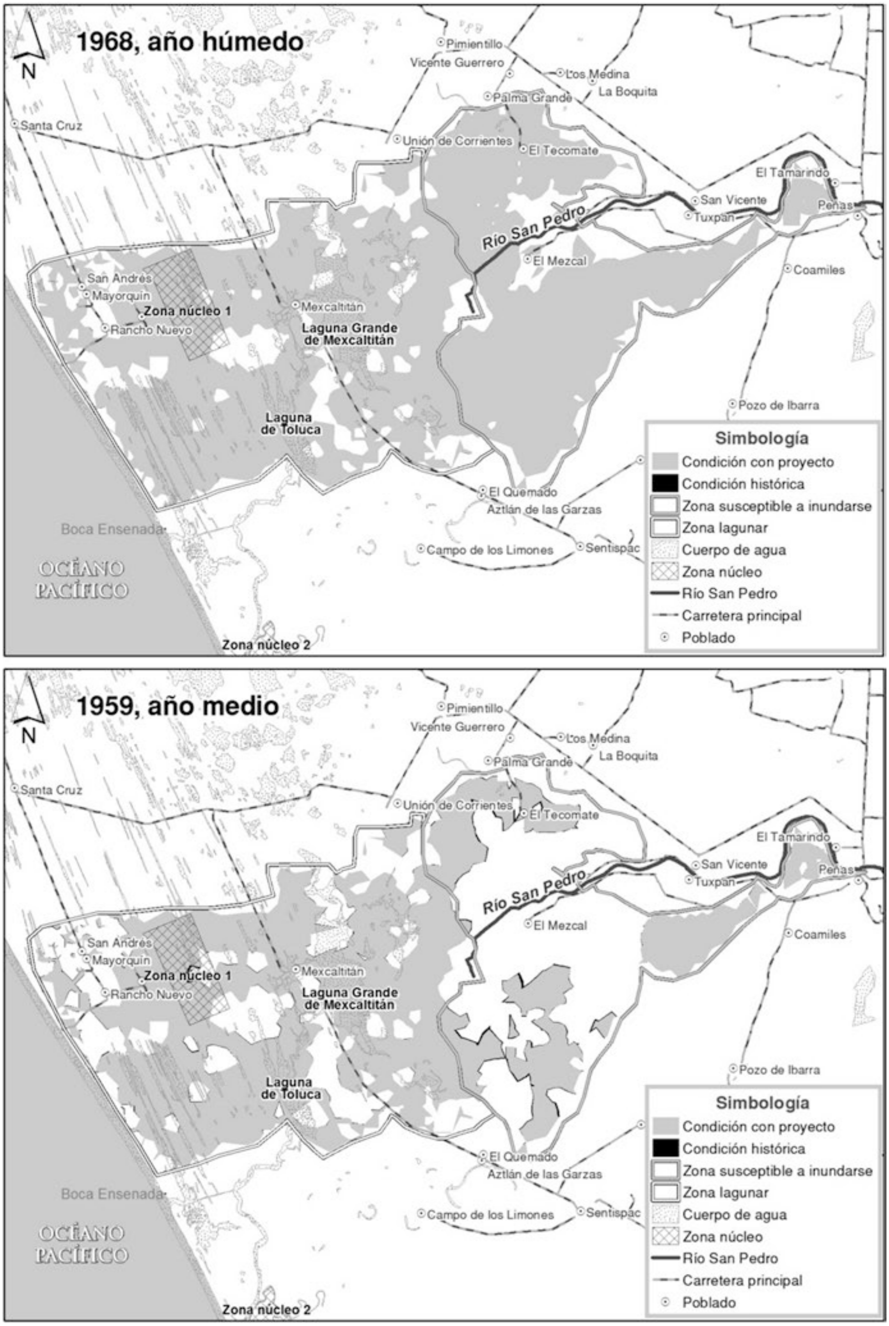

Fig. 16.13 Maximum expected extension of lagoons and flooded areas for humid and medium years. No significant differences are observed. (Modified from Universidad de Guadalajara and Comisión Federal de Electricidad 2014)

In order to reduce biodiversity disturbances derived from projects, CFE developed the procedure entitled "Selection of Sites for Electrical Substations and Routes for Transmission Line." This technical procedure establishes the social and environmental criteria for infrastructure siting. To this end, satellite and orthophotographic images, as well as literature information on where the project is required, are analyzed for identifying social, cultural, environmental, and legal issues related to the new facility.

Areas that should be avoided are:

- General roadways and industrial and tourist areas
- Forested zones; federal maritime and terrestrial zones; and federal zones comprising water bodies, rivers, streams, and lagoons
- Protected natural areas and biological corridors; terrestrial, marine, and hydrological regions that are priorities for biodiversity conservation; priority inland, marine, and hydrological regions; and areas that are important for bird conservation
- Areas susceptible to erosion

Areas that are excluded are those with legal restrictions for use as well as those where there are activities or lands that are incompatible with electric infrastructure. Only areas that will not lead to significant environmental and social impacts that cannot be prevented, mitigated, or compensated are considered.

By considering the elements mentioned above, potential routes are identified for transmission lines, as well as sites suitable for constructing substations. These site/route options are analyzed using an integrated approach to select the best from technical, social, and environmental perspectives (Comisión Federal de Electricidad 2014).

Since this procedure was implemented, disturbances to biologically important zones have been reduced, and protected natural areas are involved only when it is strictly necessary, for example, when a project objective is to bring power to zones located within them. Furthermore, when access to these zones is required, the route and characteristics of the project are thoroughly reviewed jointly with staff of the National Commission of Protected Natural Areas.

16.6.6 Vegetation Management in Power Transmission and Transformation Projects

When it is impossible to avoid natural vegetation zones, CFE applies all appropriate actions to protect flora and fauna. Standardized procedures are in place to minimize vegetation disturbances, as is the case of transmission lines and infrastructure that occupies large extensions of land. A vegetation management process has been established in the "General Environmental Specifications for the Design, Construction and Commissioning of Transmission Lines" (Comisión Federal de

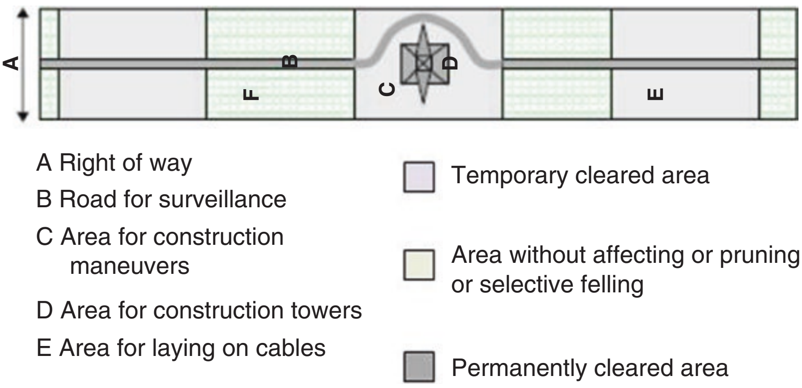

Fig. 16.14 Vegetation management within the right of way. (Modified from Comisión Federal de Electricidad 2016)

Electricidad 2016). Figure 16.14 shows how vegetation should be handled along the right of way, restricting total vegetation clearing in zones where power transmission cables can be placed closer to the ground. In areas where the height of the natural vegetation is lower, the surfaces that are cleared of vegetation are smaller.

16.7 Discussion and Conclusions

Although practically all human works and activities modify the social-environmental surroundings, the experienced gained by CFE indicates that the best management approach involves the search and selection of options that cause the lowest impact possible, since preventing impacts is far easier and cheaper than recovering the structure and/or function of socio-ecosystems.

On the other hand, although in some cases a decision to protect a particular area, ecosystem, or species may be questionable, the most convenient approach for developing projects is to avoid or minimize interactions with areas or regions that include protected species or ecosystems deemed important due to their environmental services. Since biodiversity is a key asset of Mexico, it is practically impossible to find a region of the country with no protected species. Therefore, achieving sustainability requires actions or programs that effectively mitigate or compensate for any adverse effects on ecosystems, thus allowing the permanence of environmental assets and services. The implementation of these programs, however, may be a complex issue, as human activities with a negative impact on ecosystems are common in areas where projects are executed.

For the development of management programs for protected areas, as well as to establish territorial conservation policies, consideration should be given to the needs of human communities located within regulated areas. These would lead to plan and undertake, from the beginning, all the works and actions required, including communications, power, and fuel supply, among many others. Ideally, all the entities in charge of promoting or carrying out these projects or activities should be involved.

A more effective conservation of key areas (based on their biological richness) requires considering the needs of the human communities within the regulated areas in the elaboration of management programs of protected natural areas and other territory-related legal regulations, to foster proper planning of the required projects dealing with communication, electricity, and fuel supply projects. The best approach regards involving the entities responsible for promoting or executing infrastructure or development projects to improve the living standards of human populations.

Moreover, it is also imperative to review all the standards that establish tight restrictions for the exploitation or modification of biotic resources or ecosystems. There are actions that, if properly planned, cause some disturbances on ecosystems or relevant species during the construction stage but, once completed, may lead to better conditions for the local ecosystems. This was the case of the opening of a navigation channel for the Manzanillo Liquefied Natural Gas Terminal (MLNGT), which enabled the recovery of mangrove at *Laguna de Cuyutlán*. This requires the application of a systematic approach in preparing the environmental impact analysis that should include the elements needed to make the best decisions.

A clear understanding of ecosystem structure and processes is essential to properly plan and execute mitigation or compensation measures. The case of MLNGT clearly illustrates this situation, since the authorities requested the implementation of a mangrove reforestation program at *Laguna de Cuyutlán* before the opening of the navigation channel generated the hydrodynamic conditions required for mangrove recovery. In addition, it would probably be best to have a program in place to foster favorable hydrodynamic conditions for mangroves in sites where the influence of the navigation channel influence was insufficient for this purpose, as observed in the case of the mangrove restoration program at *Laguna de Términos*.

Another topic worth discussing with the academic sector and environmental authorities is the convenience of establishing regional restoration programs; this approach would provide resources at a larger scale which is likely more efficient than applying the same resources to small programs. However, an aspect to bear in mind is that the success of these programs largely depends on achieving the involvement of the local landowners, so that they assume these programs as their own.

Yet another aspect that should be reviewed in detail includes the convenience of having two regulatory instruments ultimately intended to protect ecosystem integrity. The Environmental Impact Assessment and the Authorization of a Change of Land Use in Forest Areas (EIA and CUSTF, respectively, for the acronyms in Spanish) regulate potential impacts on biodiversity and environmental services offered by ecosystems and sometimes involve incompatible theoretical and practical considerations.

It is acknowledged that we have two different administrative processes (EIA and CUSTF) that require compliance, under two separate laws (LGEEPA and LGDFS) that show differences as well as similarities, and that are assessed and approved by the same office at SEMARNAT. This procedural duplicity rises the expenses related to studies and the time to get the approval for the execution of projects. In addition, this duplicity implies that the same impact should be mitigated or compensated twice; authorities occasionally request two different approaches to address it. In our opinion, it should be acknowledged that there is no legal basis to support that a compensation for a change of land use in forest areas cannot be compared to environmental impact, when the impact associated to vegetation clearing is actually the same.

In the future, the participation of different construction companies and operators of electric infrastructure will add to the heterogeneity of approaches for project development. In addition, the growth of the electric sector requires a planning stage that considers the social and environmental elements, as well as the potential cumulative impacts derived from development. For those reasons, a priority for the energy secretariat should be to perform a strategic environmental assessment to redefine the Development Program of the National Electric System and establish social and environmental criteria for developing the future electric infrastructure projects.

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Chapter 17
Freshwater Wetlands Conservation: An Assessment Protocol for Coastal Restoration in the Context of Climate Change

María Mercedes Castillo-Uzcanga, Everardo Barba-Macías, and Alejandro Espinoza-Tenorio

Abstract Salinization and land use changes (LUC) threat the ecological functioning of coastal wetlands, which are particularly vulnerable to climate change. The objective of this study was to develop a rapid identification and assessment protocol of threatened wetlands that have the potential for conservation and restoration. The selection of wetlands was based on a socioecological classification, including water physicochemical variables, land use estimation, land tenure, and management practices. The selected wetlands were then classified into three categories: (a) freshwater wetlands exposed to saline intrusion, (b) wetlands in agricultural areas, and (c) wetland as biological corridors. From the 18 wetlands visited, 11 were classified as wetlands in agricultural areas that can also act as corridors, and the remaining seven were wetlands exposed to salinization. Our proposal is a practical instrument for identifying potential wetland restoration sites in an area where biological, hydrological, and water quality data was limited.

Keywords Saline intrusion · Land use change · Biological corridor

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17.1 Introduction

Coastal zones provide a wide variety of ecosystem services and globally are highly populated areas (Small and Nicholls 2003; Burkett and Davidson 2013; Spencer et al. 2016). However, these areas are highly vulnerable to the effects of land use and climate change. Increased sea level and changes in the frequency and magnitude of storms and precipitation will affect processes such as coastal erosion, flooding, inputs of freshwater, and saltwater intrusion, which can alter the ecological function of coastal ecosystems (Williams 2013). Coastal wetlands are among the most threatened ecosystems by climate change (Kassakian et al. 2017). In addition, these ecosystems are also under other anthropic pressures such as land use change, pollution, and water extraction, which can influence the responses and adaptation of coastal wetlands to climate change, compromising ecosystem function and services (Andam et al. 2008; Kolb et al. 2013; White and Kaplan 2017).

Coastal wetlands comprised saltwater and freshwater wetlands, including tidal marshes, swamps, coastal streams and rivers, and their riparian and floodplain areas (Capon 2016). In a climate change context, coastal wetlands can be altered in different ways. Sea level rise can increase the effects of storms on coastal wetlands and also can enhance salinization of freshwater ecosystems and groundwater systems (Ferguson and Gleeson 2012; Herbert et al. 2015). Losses of vegetated wetlands due to its conversion into mud flats and permanently flooded areas are among the outcomes of sea level rise, and the extent of this conversion will depend on several factors such as topography, rate of sea level increase, plant productivity, and inputs of freshwater and sediments (Geselbracht et al. 2011; Schile et al. 2014; Tabak et al. 2016). Some of these factors are influenced by stressors not related to climate change such as land use changes (LUC) and dam building, which affect the amounts of freshwater and sediments that reach the coast and, in turn, plant productivity and soil accretion (Ericson et al. 2006).

Saltwater intrusion, reduced freshwater inputs, and storm surges are among the factors that enhance salinization of coastal wetlands (Herbert et al. 2015). Storm surges and waves can have impacts such as erosion, prolonged flooding, and salinization, and as sea level rises, these events can become more frequent and affect farther inland ecosystems (Morton and Barras 2011; Glick et al. 2013; Williams 2013). Salinization and flooding can alter biota composition and biogeochemical processes in wetlands (Smith et al. 2009; Craft 2012). Reduced vascular plant biodiversity is also associated with increased salinity. Responses of freshwater plants will depend on the magnitude and duration of salt intrusion pulses and the biogeochemical changes associated with the intrusion; however, freshwater plants will be replaced by more salt-tolerating species under high salinities (Stralberg et al. 2011; Herbert et al. 2015; Grenfell et al. 2016). Plant productivity is also expected to decline as salinity increases, which in turn can affect the wetland capacity to accumulate organic matter in soils and to respond to sea level rise (Neubauer et al. 2013). Changes in wetland habitat can also affect consumer biodiversity, including aquatic invertebrates, amphibians, fishes, and birds, particularly species associated with freshwater habitats and forested ecotones (Geselbracht et al. 2011; Cañedo-Argüelles et al. 2013; Veloz et al. 2013; Sims et al. 2013). In coastal rivers and streams, saline intrusion can affect water quality, riparian vegetation, and freshwater biota (Love et al. 2008; Capon et al. 2013).

Despite the threats posed by sea level rise on coastal wetlands, these ecosystems are highly dynamic and have the ability to respond to the altered conditions (Kirwan et al. 2010). Responses of coastal wetlands to sea level rise include accretion and inland migration. Accretion consists of the accumulation of inorganic and organic matter on wetland sediments (Day et al. 2016). Feedback mechanisms between sea level, plant productivity, and sediment accumulation can maintain wetland equilibrium elevation with respect to sea level, preventing their submersion under certain scenarios of sea level rise (Morris et al. 2002; Kirwan et al. 2010; Schile et al. 2014). Accretion depends on several factors such as plant productivity, tidal range, and sediment and freshwater inputs, which in turn can be affected by climate and land use changes, nutrient loading, flow alteration, impoundments, and water extraction, among other factors (Morris et al. 2002; Stralberg et al. 2011; Glick et al. 2013). Although coastal wetlands have kept up with sea level rise over thousands of years by accretion, scenarios that consider high sea level rise rates and low sediment inputs probably will decrease wetland stability and survivorship (Day et al. 2008; Kirwan and Megonigal 2013; Schile et al. 2014; Rodríguez et al. 2017). Wetland migration to adjacent uplands can compensate for losses due to sea level rise (Kirwan et al. 2016; Kassakian et al. 2017; Schieder et al. 2017). However, topography and infrastructure can interfere with wetland migration (Cadol et al. 2016; Tabak et al. 2016). Steep terrain, impervious surfaces such as roads and urban areas, and coastal defense, such as seawalls and levees, can prevent the migration of wetland inland, leading to coastal squeeze and potential wetland loss (Pontee 2013; Torio and Chmura 2013).

Services provided by coastal wetlands can be altered by climate change, by reducing their carrying capacity and compromising their resilience, a key element in mitigating the expected effects of global warming (Harley et al. 2006; Hadley 2009). Primary productivity can decline as salinity increases (Craft et al. 2009; Neubauer et al. 2013), which can have implications on food webs and secondary production (Callaway et al. 2007). Carbon and nutrient cycling can be changed by salinization, flooding, and conversion of freshwater habitats into more brackish environments (Craft et al. 2009; Herbert et al. 2015). Carbon emissions as CO_2 and CH_4 can be affected by salinization; however, the magnitude of the fluxes can also be influenced by other factors such as flooding conditions, organic matter availability, and enzyme activity (Neubauer 2013; Neubauer et al. 2013; Herbert et al. 2015). Increased salinity can reduce nitrogen retention in wetland soils and removal through denitrification, resulting in higher nitrogen export into rivers and the ocean (Neubauer et al. 2013; Herbert et al. 2015; Hinshaw et al. 2017; White and Kaplan 2017). However, changes of one type of wetland into another can increase some services and decrease others. For example, conversion of freshwater tidal forests into marshes can result in the loss of bird habitat and decreased nitrogen removal, but carbon sequestration and nitrogen and phosphorus accumulation can be higher in marsh soils (Craft 2012). Saline intrusion in tidal streams and rivers can affect nursing habitats of fishes and can have impacts on fisheries (Love 2015).

Considering these services, mitigation and restoration actions have been proposed to maintain wetland resilience to climate change impacts. To facilitate inland migration, efforts must focus on protecting low-gradient undeveloped land and restoring areas with little development (Noss 2011; Stralberg et al. 2011; Glick et al. 2013; Cadol et al. 2016; Tabak et al. 2016). In addition, land acquisition and managed realignment can also enable upland migration (Noss 2011; Doody 2013; Glick et al. 2013). To promote accretion, flow and sediment management and redesign of marsh channels have been proposed (Stralberg et al. 2011; Schile et al. 2014; White and Kaplan 2017). Furthermore, implementing corridor areas between wetland and adjacent uplands area can enhance connectivity among habitats and facilitate the migration of organisms (Maschinski et al. 2011; Noss 2011). Protection of coastal rivers, streams, draining ditches, and their riparian zones can also facilitate the upstream migration of the biota because they can act as corridors connecting the landscape (Palmer et al. 2009; Clarke 2015). To implement these strategies, it is necessary to identify areas for conservation and restoration. Criteria include biodiversity distribution, landscape connectivity, sea level rise, saline intrusion and sediment input scenarios, habitat mapping, and land use change (Veloz et al. 2013; Zhu et al. 2015; Hua et al. 2016). However, detailed information is not available for many coastal areas where sea level rise is already affecting the ecosystems, so a rapid assessment is needed to identify areas for conservation and restoration.

Since freshwater coastal wetlands are particularly vulnerable to climate change (Herbert et al. 2015; Hua et al. 2016; Tabak et al. 2016), our objective was to develop a rapid identification and assessment protocol of threatened freshwater wetlands that have potential for conservation and restoration in a region where actions to increase resilience of wetlands are particularly necessary. We conducted this study in the Carmen-Pajonal-Machona lagoon system, Tabasco, Mexico, comprising inland wetlands that are associated with lentic and lotic environments and immersed in agricultural activities. Tabasco coast has been considered one of the most threatened areas of Mexico to climate change (Botello et al. 2010). Here, the Carmen-Pajonal-Machona lagoon system is especially vulnerable because it exhibits a complex combination of adverse environmental conditions and a landscape severely altered by anthropogenic activities (Hernández-Santana et al. 2008; Núñez et al. 2016).

17.2 The Tabasco Coast

Tabasco is located Southern Gulf of Mexico (Fig. 17.1) and is one of the smallest coastal states in Mexico but contains the most important coastal wetlands in Mesoamerica (RAMSAR 2014) and the largest river system in the country, the Grijalva-Usumacinta. The alluvial coastal plain of Tabasco is occupied by an

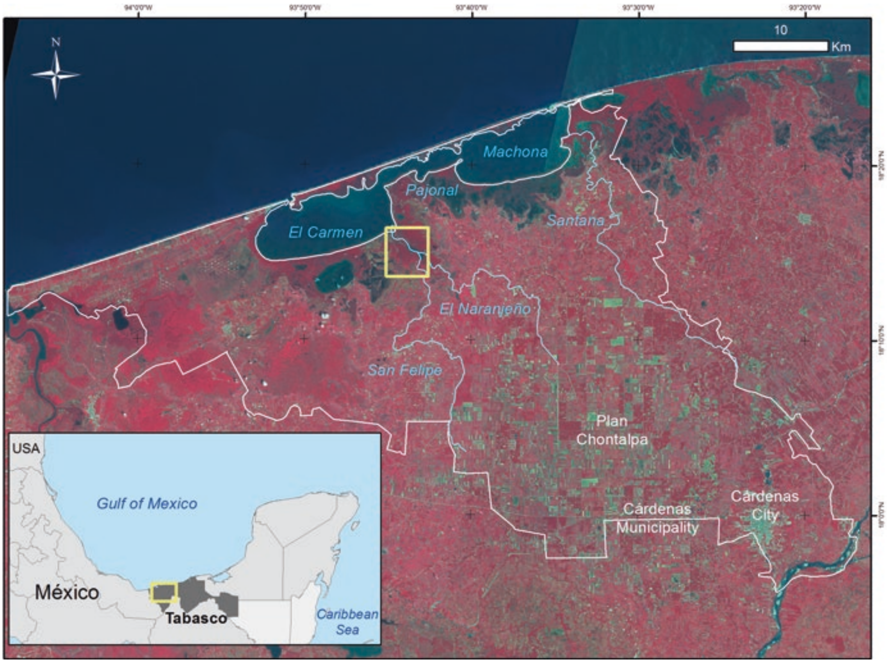

Fig. 17.1 The Carmen-Pajonal-Machona lagoon system, its main tributaries, and municipality limits

extensive and complex lowland drainage system with an average elevation of less than 1 m (SEMARNAP 1997). Low and sandy beaches dominate the coast, with the presence of barrier islands, which enclose a series of coastal lagoons covering an area of 31,902.7 ha (Rodríguez-Rodríguez 2002). These aquatic ecosystems are normally shallow (1–3 m), formed by semi-enclosed water bodies, parallel to the coast, and interconnected by shallow and narrow channels.

Along the coast of Tabasco, there are several wave regimes, determined by the influence of tropical storms, cold fronts, and trade winds from the northeast. According to the classic study of Gómez-Angulo (1977), the effect of the wind is temporal on the lagoons but can modify the circulation and, therefore, the conditions of the ecosystems. The water level of the lagoons reaches 1 m above sea level during the rainy season, when the winds modify the physicochemical properties and the circulation of the lagoons. In addition, the abundant precipitation during this season represents a significant contribution of water to the lagoons. When a cold front appears, the tide flow is favored in the same direction of the wind, while the rivers contribute a considerable amount of water; during the reflux, the water is blocked in the mouth by the opposite effect of the wind, causing the highest volumes of the year for 1 or 2 days (Gómez-Angulo 1978).

17.2.1 Intensive Land Use Change

The state of Tabasco represents a "microcosm of the rapidly changing conditions" that is occurring in many regions of the developing world (Dewey 1981, p.153). During the last six decades, the coast of Tabasco has experienced considerable agriculture and livestock development, which has resulted in a rapid expansion of land dedicated to cash crops and pastures for livestock. The origin of the current landscape around this lagoon comes from the 1950s, when the *Comisión del Río Grijalva* was created with the objective to propel the integral development of the watershed of this river. It started with an extensive drainage project to control the heavy floods that frequently affected the lower basin (Asteinza-Bilbao 1997). This commission was also the forerunner for the Plan Chontalpa (Fig. 17.1), initiated in the late 1960s to increase agricultural (sugarcane, bananas, and rice) and cattle production in the area (Dewey 1980; Arrieta-Fernández 1992). The Chontalpa covers an area of 8000 km^2; and it is limited in the north by a strip of marshes and swamps that separates it from the Gulf of Mexico (Leyva-Peña 1970). The trend toward increased agriculture and intensive cattle ranching was also accelerated by the National Tree Clearing Program operated in the 1970s (Moreno-Unda 2011).

In addition, part of the exploration and production of oil in Mexico has been conducted in Tabasco. Thus, its coast faces deforestation, loss of habitat and biodiversity, soil erosion, fragmentation, and a decline in the value of environmental goods and services (Guerra-Martínez and Ochoa-Gaona 2008; Figueroa and Sánchez-Cordero 2008; Barba-Macías et al. 2014; García-Hidalgo 2014). The recent expansion of oil production in Tabasco has also affected the coastal wetlands by building new channels and oil wells (Hanson 2002) and by increasing pollution due to oil activity (Castañeda-Chavez et al. 2014).

17.3 Methods

17.3.1 Study Area: Carmen-Pajonal-Machona Lagoon System

The Carmen-Pajonal-Machona lagoon system covers 8800 ha. Three important rivers flow into this system at its southern margin: (1) the San Felipe and (2) the Naranjeño to El Carmen lagoon and (3) the Santa Ana to La Machona lagoon (Fig. 17.1). This coastal lagoon system has low salinity, but it can show seasonal and daily variations.

Aquatic vegetation is divided into tular, popal, and seagrass. The tular is a hydrophilic plant community found in permanent marshy areas and is dominated by *Typha latifolia*. The popal is also a hydrophilic plant community dominated by *Thalia geniculata*, and it is found year-round in flooded areas and represents an important habitat for fish species, turtles, and migratory birds. In the transition zone, the popal and tular are associated with *Acrostichum aureum* and *Mimosa pigra*. Much of the bottom of the lagoon system is occupied by silty-clayey material with numerous oyster banks, while near the bars, the bottom is sandy and covered by the algae *Halodule wrightii* (Barba-Macías 2005).

There are arboreal and arborescent communities that can get flooded: floodplain forests, riparian high forest, riparian evergreen forest, and floodplain palm. Vegetation around the lagoons is dominated by mangrove species such as *Rhizophora mangle*, *Avicennia germinans*, *Laguncularia racemosa*, and *Conocarpus erectus* (Novelo and Ramos 2005). Coastal vegetation is primarily herbaceous and represented by the pioneer species *Ipomoea pes-caprae* and *Croton punctatus* as a typical dune flora, while the vegetation of the stabilizing zone has completely been replaced by coconut trees (Pérez-y-Sosa 2005).

Carmen-Pajonal-Machona is recognized by its high levels of fish, agriculture, livestock, and forestry production (Castañeda-Chavez et al. 2014). Fishing in the Tabasco lagoons has been carried out for more than 500 years (Alcalá Moya 1986), but at present, the fishing fleet consists mostly of small canoes and fiberglass boats. Local fisheries primarily target shrimp (*Litopenaeus setiferus*, *Farfantepenaeus aztecus*, *F. duorarum*), snail (*Melongena melongena*), crabs (*Callinectes sapidus*, *C. rathbunae*, and *C. similis*), as well as finfish such as *Centropomus parallelus*, *C. undecimalis*, *Cichlasoma urophthalmum*, *Paraneetroplus synspilus*, *Mugil curema*, and *M. cephalus* (INAPESCA 2007).

Other productive activities are aquaculture, agriculture, and extensive cattle ranching. Aquaculture includes small-scale and extensive production of tilapia (*Oreochromis* spp.), shrimp (*Litopenaeus setiferus*, *Farfantepenaeus aztecus*, and *F. duorarum*), and oysters (*Crassostrea virginica)*. The oyster catch from Tabasco coastal lagoons has come to represent up to 60% of the total volume of the fishing catch of the entity (Garrido-Mora et al. 2007), reaching up the second place in the national production (CONAPESCA 2005). In the region, the most important crops are cocoa, corn, sugarcane, copra, banana, orange, lemon, rice, and beans, which are mostly seasonal (Magaña et al. 2011). In addition, the local communities use the tular vegetation to make handicrafts, mats, toys, and other domestic utensils (INAPESCA 2007).

17.3.2 Assessment Protocol

The protocol is divided into four main stages (Fig. 17.2). This multidisciplinary methodology was designed to assess and map threatened wetlands that have the potential for conservation and restoration. The approach uses a conjunction of tools and indicators in a context of data-poor areas and urgent natural resource decision-making.

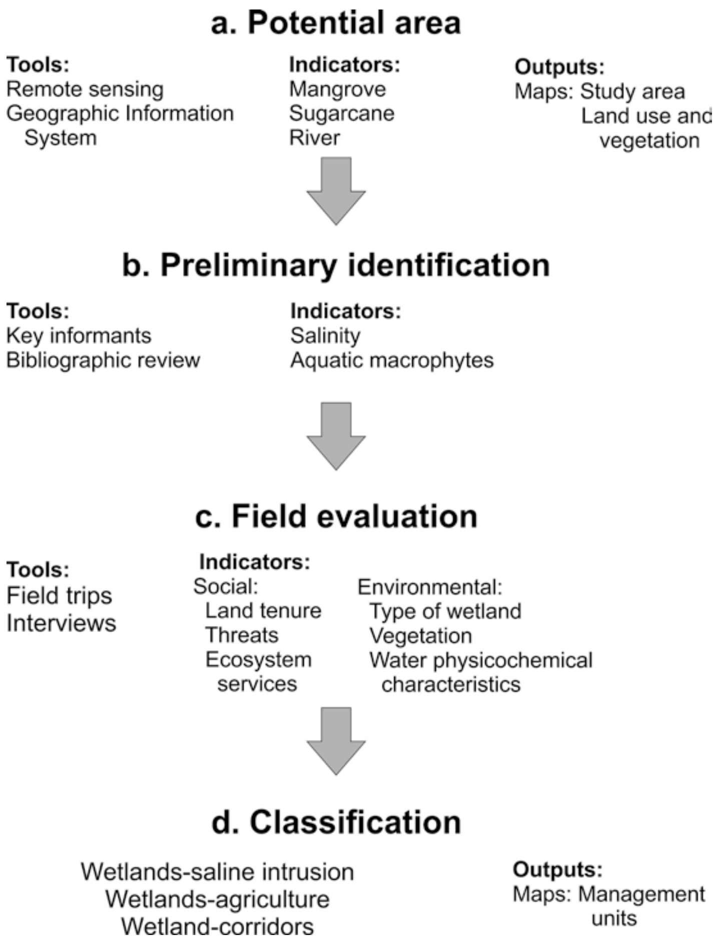

Fig. 17.2 Methodological diagram with four main stages

17.3.2.1 Identifying the Potential Study Area

A first step was to define an area where freshwater wetlands could be found. A prospective analysis through SPOT images (1:20,000) of the area located south of El Carmen lagoon (Fig. 17.3) and geographic information systems (GIS) allowed the delimitation of a rectangular polygon using the following ecological and spatial criteria (Table 17.1). A supervised classification analysis scale 1:20,000 identified the mainland uses and dominant vegetation cover in the potential area.

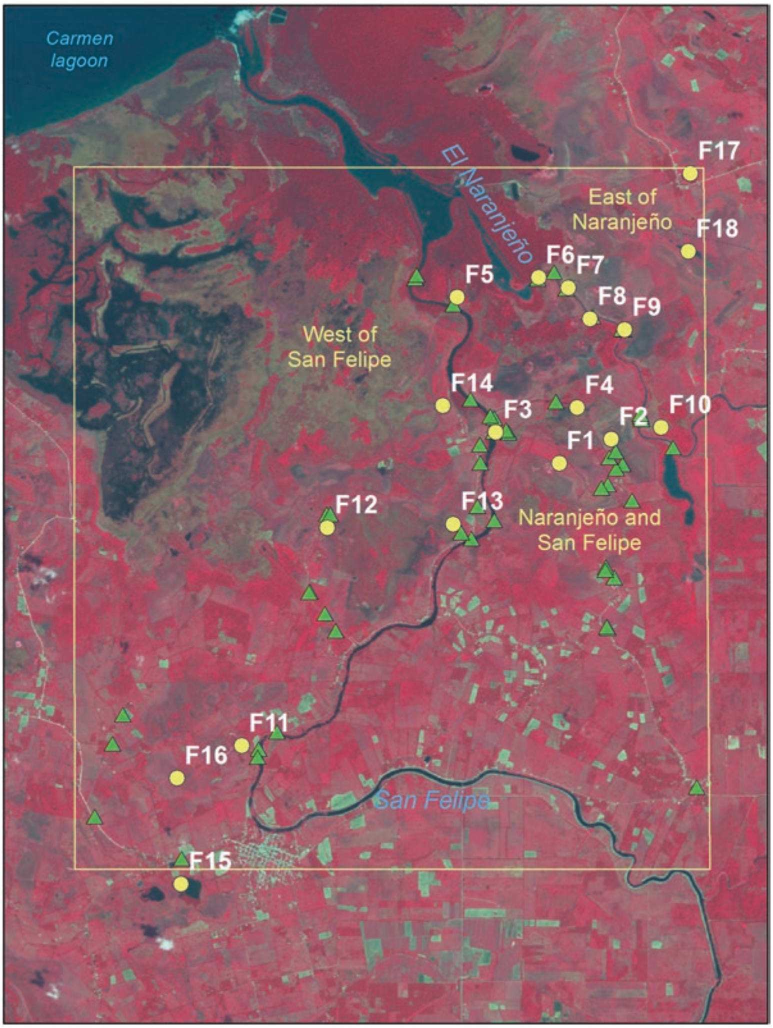

Fig. 17.3 Polygon definition and visited sites: points of reference (yellow) and documented sites (green)

Table 17.1 Criteria for delimitation of context area of coastal wetlands

Indicator	Definition	Study area
Mangrove cover	Salinity-tolerant plant communities	Northern border
Sugarcane crops	Changes in soil type and water availability	Southern border
River	Freshwater source	Eastern and western borders were set based on the influence area of the El Naranjeño and San Felipe rivers, respectively

Table 17.2 Indicators used to classify wetlands subject to saline intrusion

	Indicator	Value	Definition	Source
	Salinity	>0.5‰	Limit value between freshwater ecosystem and oligohaline ecosystems	Cowardin et al. (1979) and UNAM (2011)
Direct	Aquatic macrophytes	Absence of *Eichhornia* sp. and *Pistia* sp.	Because *Eichhornia* sp. and *Pistia* sp. do not tolerate salinity values above 3.33 and 2.5‰, respectively, the absence of these plants could indicate that the wetland has experienced salinity levels above these values	Haller et al. (1974)
Indirect	High salinity	Presence/absence	Key informants: indications of the inhabitants that the area is subject to the entry of water with high salinity during the year. Additional evidence came from reports of salinization of water wells	Academics

17.3.2.2 Preliminary Wetland Identification and Classification

Wetland identification was based on vegetation type and open water areas. Tular and popal areas located within the selected polygon were identified as potential wetland areas as well as areas that showed water accumulation such as small ponds, channels, and rivers. These areas were identified in the image based on change in texture related with a particular class of land cover. The selected freshwater wetlands were then classified into three categories: wetlands exposed to saline intrusion, wetlands in agricultural areas, and wetlands as biological corridors. The first two categories responded to the interest in identifying areas that are currently experiencing saline intrusion or land use pressure, which can be candidates to restoration. Agricultural areas include pasture and were selected among other land uses because they are dominant in the study area. The biological corridor categories were wetlands that considering their location in the landscape can act as connectors between different areas of the landscape to facilitate organism migration. The categories are not exclusive since there may be agricultural wetlands subject to saline intrusion or serve as a corridor.

- *Freshwater wetlands exposed to saline intrusion*: They are interior wetlands that show water inlets with high salinity. Saline intrusion due to tidal effects occurs mainly during the dry season; therefore, to identify the wetlands subject to this process, the following direct and indirect indicators were defined (Table 17.2).
- *Wetlands in agricultural areas*: Wetlands immersed in a matrix of agricultural land use, characterized by the presence of crops, cultivated pastures, or livestock. These transformations have changed wetland structure and composition of species. However, many of these areas retain characteristic features of wetlands such as hydrology and soil type.

- *Wetlands as biological corridors*: Wetlands that given their location, current condition, and adjacent land use can be part of a corridor that allows the movement of aquatic and riparian species in the landscape. This category included areas with lower anthropogenic pressure. Corridors may also be the target of restoration actions.

Preliminary classification only included wetlands in agricultural areas and wetlands as corridors, considering that assigning the wetland exposed to saline intrusion category requires field visits.

17.3.2.3 Field Assessment

For programming the field visits to the potential area, points of reference were selected based on previously identified wetlands (Fig. 17.3) and located in three large areas: (a) east of the El Naranjeño River, (b) between the El Naranjeño and San Felipe Rivers, and (c) west of the San Felipe River. These areas were delineated to facilitate and optimize field visits based on access by road or boat to the reference points.

At each visited site, the wetland area was surveyed, collecting technical data following the National Wetlands Inventory recommendations (UNAM 2011). Data included (1) geographic coordinates, (2) type of wetland (e.g., lagoon, popal, river), (3) terrestrial and aquatic vegetation, (3) physicochemical aspects of water, (4) anthropogenic land use, (5) threats, and (6) ecosystem services.

Conductivity, salinity, dissolved oxygen concentration, percentage of oxygen saturation, and pH were measured with an YSI Model 65 probe. In the San Felipe and El Naranjeño rivers, as well as in some tributary channels, measurements were made at the surface and the bottom, while in the wetlands and flooded areas, measurements were taken at the surface level when enough water was present.

Botanical samples (leaves, flowers, and fruits) of plants representative of the wetland were collected, in addition to photographs taken, for posterior identification of species, with the support of the herbarium of the "Universidad Juárez Autónoma de Tabasco," and specialized literature (Cowan 1983; Pennington and Sarukhán 2005).

Inhabitants were interviewed regarding the identified wetlands, in order to characterize the vegetation representative of the study area, as well as land tenure, human activities, and the presence of saline intrusion.

17.3.2.4 Final Classification of Wetlands

Once the cartographic and image information was analyzed and integrated with the data collected in the field, wetlands were classified in wetlands exposed to saline intrusion, (b) wetlands in agricultural lands, and (c) wetlands as biological corridors. Wetlands were organized in groups based on their location. For each group, area covered by wetlands was estimated.

17.4 Results

Fourteen types of land use and covers were identified in the study area (Fig. 17.4), including four types of vegetation (freshwater wetlands, 34.6%; herbaceous, 20.5%; mangrove, 6.9%; "acahual" (secondary vegetation), 3.9%), four land uses (pastureland, 24.4%; sugarcane, 5.3%; cocoa, 0.8%; urban, 0.7%), and four

Fig. 17.4 Land use and natural covers in the study area located south of El Carmen lagoon. Vegetation: freshwater wetlands (3970 ha), herbaceous (2355 ha), mangrove (791 ha), and acahual (451 ha); Land uses: pastureland (2798 ha), sugarcane (611 ha), cocoa (87 ha), and urban (85 ha); and Water bodies: rivers (283 ha), lagoons (22 ha), artificial channels (16 ha), and aquaculture (9 ha)

types of water bodies (rivers, 2.5%; lagoons, 0.2%; artificial channels, 0.1; aquaculture, 0.1%).

Most of the area belongs to the "ejido" property (77%), while private property is around 33% (Table 17.3). The ejido is a Mexican community-based land tenure system, where land is divided into three main uses: human settlement, common use lands (including forests, water sources, and other resources), and parceled land for individual exploitation.

17.4.1 Wetland Field Assessment

Eighteen sites were documented (Table 17.3). Most sites were located in lentic and flooded areas, except for the main channels of the El Naranjeño and San Felipe Rivers and artificial channels. Vegetation at the visited sites generally exhibited a combination of trees, shrubs, pasture, and aquatic vegetation. Aquatic vegetation comprised different types of macrophytes, including free-floating (*Eichhornia crassipes, Salvinia*, *Pistia*), floating-leaved (*Nymphaea ampla*), emergent (*Typha, Juncus*), and submerged (*Cabomba*). Birds were commonly observed at the visited wetlands.

17.4.1.1 Physicochemical Variables of Water

In rivers, streams, and channels, conductivity and salinity varied between 284 µS cm^{-1} and 0.13‰ in a tributary of the San Felipe River and 2589 ųS cm^{-1} and 1.33‰ in the bottom of the San Felipe River, near its confluence with El Naranjeño River (Table 17.4). The highest values of conductivity and salinity were observed in the main channel of the San Felipe River and in the artificial channel located on its right margin. Salinity values above 0.5‰ define the boundary between freshwater ecosystem and oligohaline ecosystems, which could indicate saline intrusion in the San Felipe River. On the contrary, the Naranjeño River showed lower values of salinity than the San Felipe River, both at the surface and the bottom. In the wetlands, conductivity and salinity ranged between 339 µS cm^{-1}, and 0.16‰ in an area dominated by *Cyperaceae* and *Typha* sp. and 9534 ųS cm^{-1} and 5.3‰ in a swamp located on the right bank of the San Felipe River and close to the channel that also had high salinity. In several wetlands, salinity values were above 0.5‰, which indicate a transition from the freshwater system to oligohaline systems.

Local reports indicate that the salt wedge enters the San Felipe River up to the bridge located east of Ignacio Gutiérrez Gómez (18 ° 9′48.49 ″N, 93 ° 42′42.98″ W) and that the El Naranjeño River is also affected by the entrance of salt water but to a lesser degree than the San Felipe River. According to these reports, the entry of high salinity water, called by the local people "flooding tide," occurs mainly in the dry season, advancing through the river main channel, stream and artificial channels, flooding lands and affecting wetlands and water bodies.

Table 17.3 Description of each visited wetland

ID: category	Description	Vegetation		Land tenure/use	Avifauna	Threats		Water quality				
		% cover	Aquatic vegetation			Cause/stressor		pH	DO(mgL^{-1})	DO(%)	Conduc. (μS cm^{-1})	Salinity(‰)
F1: 2,3	Lentic. Marsh/vegetated ditch	Shrubs (30%), trees (20%), pasture (10%). Aquatic macrophytes: emergent (30%) and free-floating (10%)	*Eichhornia crassipes*, *Salvinia* sp., *Lemna* sp.	Private cattle ranching		Cattle ranching	Soil erosion and compaction	6.8	6.89	90.6	450	0.21
						Roads and levees	Fragmentation					
F2: 1,2,3	Lentic /pond	Pasture (40%), shrubs (10%), trees (10%). Aquatic macrophytes: free-floating (20%), emergent (10%), floating-leaved (10%)	*Eichhornia crassipes*, *Nymphaea ampla*	Privatecattle ranching	*Ardea alba*, *Bubulcus ibis, Caracara cheriway*	Roads and levees	Fragmentation	7.6	5.99	86.3	1091	0.53
F3: 2,3	San Felipe River and riparian zone. Lotic/lentic/marsh	Marsh with: shrubs (60%), pasture (25%), trees (15%). Aquatic macrophytes: emergent (15%)	*Eichhornia crassipes*, *Typha* sp., *Juncus* sp., *Cabomba* sp.		*Dendrocygna autumnalis*, *Platalea ajaja*, *Caracara cheriway*, *Phalacrocorax auritus*	Oil activity	Fragmentation, pollution	7.8	4.92	64	602	0.29
						Cattle ranching	Soil erosion and compaction					
F4: 1,2,3	Artificial channel and marsh/lotic/lentic	Marsh with: trees (25%), shrubs (15%). Aquatic macrophytes: emergent (50%), free-floating, floating-leaved, submerged (10%)	*Salvinia* sp., *Lemna* sp., *Nymphaea ampla*, *Typha* sp., *Cabomba* sp., *Juncus* sp.	Privatecattle ranching	Presence of birds	Oil activity	Fragmentation, pollution	7.3	9.5	136	9534	5.3
						Cattle ranching	Soil erosion and compaction					

F5: 1,2,3	Lentic/flooded area/marsh	Trees (50%), shrubs (10%). Aquatic macrophytes floating-leaved (15%), submerged (15%), free floating (5%) emergent (5%)	*Nymphaea ampla*, *Pistia* sp., *Lemna* sp., *Cabomba* sp.	Ejidal, cattle ranching	*Jacana spinosa, Coragyps atratus*	Oil activity	Fragmentation, pollution	7.9	8.62	119	2091	1.105
F6: 2,3	El Naranjeño River and riparian zone. Lotic/lentic/	Trees (40%), pasture (20%). Aquatic macrophytes: emergent (30%),free-floating (20%)	*Eichhornia crassipes*, *Typha* sp., *Juncus* sp.	Ejidal, cattle ranching	Presence of birds	Oil activity	Fragmentation, pollution	8.2	7.26	94.4	717	0.35
F7: 2,3	Lentic/flooded area, marsh	Pasture (40%), trees (15%), shrubs (10%). Aquatic macrophytes: emergent(20%), free-floating (10%), and floating-leaved (5%)	*Typha* sp., *Nymphaea ampla*	Ejidal, cattle ranching	Presence of birds	Cattle ranching	Soil erosion and compaction					
F8: 2,3	Lentic/marsh	Mangrove, secondary forest	*Eichhornia* sp., *Nymphaea ampla*, *Juncus* sp., *Typha* sp.	Privatecattle ranching	*Ardea alba*	Cattle ranching	Soil erosion and compaction					
F9: 2,3	El Naranjeño River and riparian zone. Lotic/lentic/ marsh	Trees (30%), pasture (10%). Aquatic macrophytes: emergent (60%)	*Typha* sp., *Juncus* sp.	Ejidal, cattle ranching	Presence of birds	Cattle ranching	River bank erosion, soil erosion, and compaction	8.3	7.26	92.9	632	0.3

(continued)

Table 17.3 (continued)

ID: category	Description	Vegetation		Land tenure/use	Avifauna	Threats		Water quality				
		% cover	Aquatic vegetation			Cause/stressor		pH	DO(mgL^{-1})	DO(%)	Conduc. (µS cm^{-1})	Salinity(‰)
F10: 2,3	Lentic/flooded area adjacent to secondary forest	–	*Typha* sp.	Ejidal, cattle ranching	Presence of birds	Cattle ranching	Soil erosion and compaction					
F11: 1,2,3	Lentic, marsh/popal-tular	Trees (30%), pasture (20%). Aquatic macrophytes: emergent (40%), free-floating (10%)	*Typha* sp., *Thalia geniculata*, *Salvinia* sp., *Pistia stratiotes*	Ejidal, cattle ranching	Presence of birds	Cattle ranching, sugarcane mill	Soil erosion and compaction Pollution	7.3	5.57	68	339	0.16
F12: 1,2,3	Lentic, marsh/popal-tular	Pasture (40%), trees (10%). Aquatic macrophytes: emergent (25%) and free-floating (25%)	*Typha* sp., *Thalia geniculata*	Ejidal, cattle ranching Temporal agriculture	Presence of birds		Groundwater salinization	7.2	2.5	31.8	772	0.38
F13: 2,3	Lentic/marsh	Pasture (20%), trees (20%). Aquatic macrophytes: Emergent (25%), free-floating (10%), submerged (15%)	*Nymphaea ampla*, *Typha* sp., *Cabomba* sp.	Ejidal, cattle ranching	*Nyctanassa violacea, Jabiru mycteria*, *Jacana spinosa*, *Phalacrocorax auritus*	Cattle ranching, sugarcane mill	Soil erosion and compaction Pollution	7.7	6.84	88.1	642	0.31
F14: 1,2,3	Marsh/flooded area with pasture	Pasture (40%), shrubs (15%), trees (10%). Aquatic macrophytes: emergent (30%) and free-floating (5%)	*Typha* sp., *Cyperus* sp.	Private cattle ranching	Presence of birds	Cattle ranching, sugarcane mill	Soil erosion and compaction Pollution	7.0	1.6	20	1720	0.86

F15: 1,2,3	Lentic/flooded area with secondary vegetation, scattered trees	Pasture (50%), trees (5%), shrubs (5%). Aquatic macrophytes: emergent (40%)	*Nymphaea ampla*, *Salvinia auriculata*	Ejidal, cattle ranching	*Nyctanassa violacea*, *Jabiru mycteria*, *Jacana spinosa*, *Phalacrocorax auritus*	Cattle ranching, sugarcane mil Sea level rise	Soil erosion and compaction Pollution salinization					
F16: 2,3	Marsh/ cultivated pasture, secondary vegetation, grazing area with scattered trees	Pasture (10%), trees (25%), shrubs (5%). Aquatic macrophytes: emergent (50%), free-floating (10%)	*Cynodon plectostachyus*	Ejidal, cattle ranching Agriculture (Cocoa, corn) Fishing	*Nyctanassa violacea*, *Jabiru mycteria*, *Jacana spinosa*, *Phalacrocorax auritus*	Cattle ranching, oil activity	Erosion (gully formation)					
F17: 2,3	Lentic marsh/ flooded area with secondary vegetation, scattered trees in grazing area	Pasture (60%), trees (10%), shrubs (10%). Aquatic macrophytes: emergent (18%), free-floating (2%)	*Nymphaea ampla*, *Salvinia auriculata*	Ejidal, cattle ranching Temporal agriculture	*Nyctanassa violacea*, *Jabiru mycteria*, *Jacana spinosa*, *Phalacrocorax auritus*	Cattle ranching, oil activity	Erosion (gully formation					
F18: 2,3	Lentic/marsh cultivated pasture, secondary vegetation, grazing area with scattered trees	Pasture (40%), trees (30%), shrubs (5%). Aquatic macrophytes: free-floating (20%), emergent (5%)	*Cynodon plectostachyus*, *Nymphaea ampla*, *Salvinia auriculata*	Ejidal, cattle ranching	*Nyctanassa violacea*, *Jabiru mycteria*, *Jacana spinosa*, *Phalacrocorax auritus*	Cattle ranching, oil activity	Erosion (gully formation					

Wetland category: (1) wetland-saline intrusion; (2) wetland-agriculture; (3) corridor

Table 17.4 Water chemistry variables at San Felipe and El Naranjeño rivers and its tributaries

Latitude	Longitude	Description	Site	Depth (m)	T (°C)	pH	DO (mg L^{-1})	DO (%)	Conduc. (μS cm^{-1})	Salinity (‰)
18°12′53.0″	93°42′26.4″	San Felipe (upstream)	F3	0.5	27.6	7.8	4.92	64	602	0.29
			F3	1	27	7.72	4.01	49.9	604	0.29
18°14′15.1″	93°43′09.6″	San Felipe (downstream from confluence with El Naranjeño)	–	0.5	28.5	8.39	8.83	114	1583	0.79
			–	2	27.8	8.06	5.62	72	2589	1.33
18°13′06.1″	93°41′41.9″	Artificial channel	F4	0.5	28.5	8.1	6.75	87.3	1267	0.63
			F4	1.5	27	7.65	4.45	57	1352	0.68
18°13′47.1″	93°41′17.5″	El Naranjeño (upstream)	F9	0.5	27.9	8.26	7.26	92.7	632	0.3
			F9	2	27.8	8.2	7.07	90.1	606	0.3
18°14′14.2″	93°42′03.4″	El Naranjeño (upstream from confluence with San Felipe)	F6	0.5	28.9	8.25	7.26	94.4	717	0.35
			F6	1.5	28.4	8.18	6.14	79.2	729	0.35
18°10′02.6″	93°44′35.7″	Stream	–		27	7.19	1.25	15.8	284	0.13
18°11′28.9″	93°44′07.9″	Artificial channel	–	0.5	27.8	7.57	3.9	49.8	782	0.38
				1	27.2	7.5	2.44	31.1	780	0.38

In wetlands, pH was between 6.82 (channel with vegetation) and 7.7 (pond) (Table 17.3). Dissolved oxygen concentration and percent saturation varied between 1.6 mg L^{-1} and 20% in a wetland located in a grazing area and 9.5 mg L^{-1} and 136% in a marsh area. Despite the shallow depth, no anoxia conditions were observed, and on the contrary, some sites exhibited oxygen over-saturation (>100%) that may be associated with high primary productivity in the water.

17.4.1.2 Threats and Ecosystem Services

Several activities linked to land use change such as cattle ranching, oil exploration, road construction, and sugarcane mills occur in the study area. Pasture for cattle grazing is very common near the visited wetlands, and it is associated with soil compaction and erosion. Deforestation of the riparian zone of the El Naranjeño and San Felipe rivers probably is associated with the observed bank erosion. Oil exploration has built several channels from the river into the wetlands, which can facilitate the movement of the saline intrusion and pollutants further inland. According to the local inhabitants, wastewater discharged from sugarcane mills located upstream from the study area can have a high impact on the San Felipe River, particularly during the dry season. These impacts particularly concerned local producers, who were contemplating strategies to reduce the inputs of high salinity and polluted water through streams and channels into their lands.

17.4.2 Wetland Classification

The area covered by freshwater wetlands represents 39,696 ha in the study area. From the 18 wetlands visited, 11 were classified as wetlands in agricultural areas that can also act as corridors, and the remaining 7 were wetlands that are expose to salinization but also are in agricultural areas and could be part of biological corridors. Most of the eight wetland areas are located in the western area (H1 = 32.4%), while southern and the zone between Naranjeño and San Felipe rivers have 21% and 25%, respectively (Fig. 17.5). Most wetlands (16) were located in pasture areas, while two were agricultural areas with the 21.6% of the area.

The Naranjeño and San Felipe rivers can constitute corridors to connect the El Carmen lagoon with the wetlands south of this lagoon. Likewise, some tributaries (streams and artificial channels) can contribute to connect the rivers with the wetland areas. Most of the wetland areas identified for conservation and restoration in this project are located less than 500 m from the river bank, so it is proposed to develop a buffer band of 500 m each side of the Naranjeño and San Felipe rivers where restoration and conservation actions can be carried out to maintain connectivity in the landscape and allow the movement of terrestrial and aquatic species.

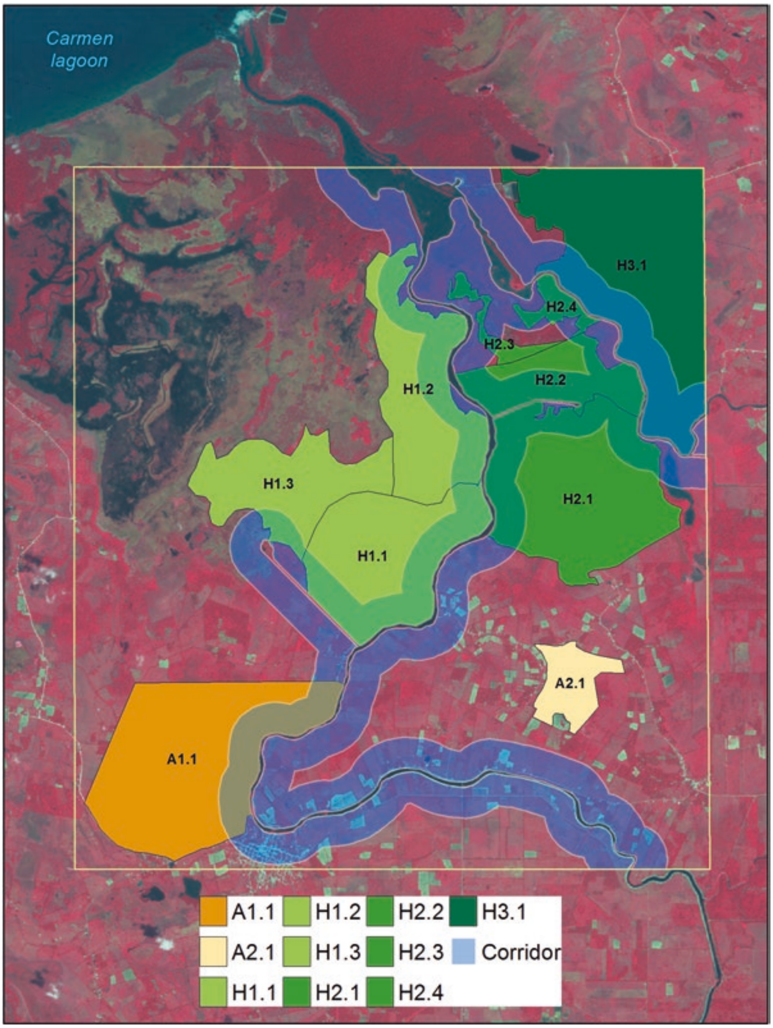

Fig. 17.5 Priority wetlands. Freshwater wetlands, H1.1 (481.2 ha), H1.2 (457.5 ha), H1.3 (348.7), H2.1 (667.8 ha), H2.2 (226.6 ha), H2.3 (47 ha), H2.4 (50.5 ha), and H3.1 (831.9 ha) and wetlands in agricultural areas, A1.1 (118.8 ha) and A1.2 (739.6 ha)

17.5 Discussion

Potential impacts by climate change on the Mexican coast must be evaluated, because it comprises 1,567,000 ha of wetlands and 1350 insular elements (CONABIO et al. 2007). However, national effectiveness in combating increasing human impacts on coastal ecosystems has been questioned (Camacho-Ibar and Rivera-Monroy 2014), even in coastal protected areas (Micheli 2002; Bezaury-Creel 2005; Ortiz-Lozano et al. 2009; la Rosa-Velázquez et al. 2017). This situation has exacerbated the natural vulnerability of climate change on coastal wetlands. The losses in services provided by freshwater wetlands, such as food (fish) and freshwater provision and storage of blue carbon, are probably due to alteration of nutrient supply and an effect of rising surface temperature (Rodríguez-Labajos 2013).

Tabasco is a low-lying area that has historically suffered from flooding and that is projected to be affected by climatic change effects such as sea level rise as well as by increasing extreme climatic events (SERNAPAM 2011). However, some of the most prevalent and serious threats could be prevented, mitigated, or reversed. A concerted policy effort to address the most pervasive and widespread threats—agriculture and oil production—would probably result in significant improvements to local conditions.

In the study area, freshwater wetlands are threatened by sea level rise and human development, as other ecosystems in low-lying coastal areas are currently experiencing (Noss 2011). Land use changes in the San Felipe and El Naranjeño catchments probably affect water quality and quantity, which can have negative impacts on freshwater wetlands. Conversion of native vegetation into pasture and agricultural areas probably is also affecting the current freshwater wetlands and their services. In addition, areas with higher salinity were associated with artificial channels constructed for oil exploration and extraction activities. These alterations can also compromise the responses of wetlands to sea level rise. Thus, the most urgent management weaknesses could be addressed, with a modicum of resources, creating the corridors and restoring wetlands in agricultural lands.

As sea level continues increasing, it is likely that saline waters from the El Carmen lagoon will continue moving inland (Fig. 17.1). Freshwater wetlands and organisms that require freshwater conditions probably will try to migrate inland. Under this scenario, rivers, streams, and channels can facilitate the movement of organisms in the landscape. Using the San Felipe and El Naranjeño rivers and their tributaries as corridors probably will require reforestation of the riparian areas and create strategies to reduce pollutant inputs into the rivers and maintain enough provision of freshwater in the river channels. These actions can create the capacity for terrestrial and aquatic biota to move further inland along river and stream channels (Catford et al. 2013). Even artificial channels and ditches can favor the migration of species in the landscape (Love et al. 2008; Clarke 2015).

In addition to corridors, it is necessary to protect and restore lowland areas with low development (Noss 2011), so there is space in the landscape to accommodate migrating freshwater ecosystems. Restoring wetlands in agricultural lands in the study area will require identifying the main disturbance to address its impacts. Protecting and restoring upstream areas for future wetland migration probably are viable in the study area due to the extensive use of pastures. Restoration of these wetlands most likely will involve reforestation and protection from cattle but also restoring the hydrological connectivity or managing saltwater intrusion that may need engineered solutions (White and Kaplan 2017).

Our proposal is a practical instrument for identifying potential wetland restoration sites in an area where biological, hydrological, and water quality data was limited.

Wetland location, characteristics, and threats were assessed, which can help to accelerate the definition of actions and strategies to mitigate the impacts of climate change. If identified areas are considered in future restoration efforts, best practices can be implemented, for instance, the correct place for the construction of infrastructure such as channels and water control structures or the best area for land acquisition and reforestation. Large-scale restoration projects can be then aimed at improving the coastal resiliency and even reducing flood risk after significant damage from extreme climatic events (Widis et al. 2015).

17.6 Final Remarks

Assessing the threatened wetlands that have the potential for conservation and restoration can enable policymakers to develop strategic, system-wide responses to pervasive management problems. The rapid assessment methodology is one of the several tools recently developed to identify threatened wetlands (e.g., Beechie et al. 2008; Widis et al. 2015). The primary aim of such assessments is to elucidate threats and conservation weaknesses, which can enable policymakers to improve management practices and reduce threats. In natural resource management, the challenge is not the difficulty of improving the effectiveness of the planning instrument; it is the will to take serious steps to do so (Ervin 2003).

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Part III
Case Studies

Chapter 18
Community Adaptation to Climate Change and Biodiversity Conservation in Natural Protected Areas: The Case of El Vizcaíno Biosphere Reserve, Mexico

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Abstract Climate and economic change put pressure on the use of natural resources, which in turn increases the vulnerability of ecosystems and human communities. This makes social participation essential for biodiversity conservation. This chapter addresses community perceptions on adaptation to climate change in El Vizcaíno Biosphere Reserve (REBIVI), in Baja California Sur (Mexico), one of the largest natural protected areas in Latin America. Workshops with local producers and community representatives show the need to increase knowledge on climate change issues and strengthen institutional and legal capacities to facilitate the implementation and monitoring of adaptation actions. At the same time, experiences already in place in REBIVI (such as whale watching, mangrove recovery, and bighorn sheep hunting) demonstrate that a responsible use of biodiversity can contribute both to conservation and community welfare and provide grounds to pursue alternative economic and social ways to relate to nature. Yet, economic growth models and the community members' heterogeneous capabilities to better adapt to climate change and strengthen their capacities for action need to be taken into account if both human welfare and conservation are to be effectively promoted.

Keywords Community adaptation · Climate change · El Vizcaíno Biosphere Reserve · Mexico

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18.1 Introduction

The environmentally adverse effects of contemporary economic growth on life—and the economy itself—have given rise to the acceptance of mitigation and adaptation mechanisms in policy agendas worldwide. The role of natural protected areas (NPAs), as clearly defined geographical spaces managed to achieve long-term conservation of nature with associated ecosystem services and cultural values (Dudley 2008), has become even more important in the context of global change. Relevant to this are local inhabitants' economic practices and living standards since the lack of income alternatives, lifestyles, and inequality are among the most common factors that constrain the implementation of adaptation and mitigation options and, in turn, strongly influence vulnerability to climate change and the emission of greenhouse gases (IPCC 2014:94–95).

Recognizing that improving community resilience to climate change in NPAs can initiate productive processes that both strengthen development opportunities and lead to improved biodiversity conservation. Seventeen climate change adaptation programs targeting populations in NPAs have been advanced in Mexico, one of them in El Vizcaíno Biosphere Reserve (REBIVI). REBIVI is located in the municipality of Mulegé, Baja California Sur (BCS), in northwestern Mexico; with an area of 2,546,790 hectares (ha), it is one of the largest NPAs nationwide (INE-SEMARNAT 2000). This space hosts high biological diversity, which includes endemic species. However, the challenge is to match biodiversity conservation with natural resource consumption by foreign investors and local communities. Situated in an arid region, REBIVI is currently subject to pressure from climate and economic change, which increases the vulnerability of human communities and ecosystems in the area. In addition to this, Mulegé shows higher rates of social marginalization in the state when compared to the other four municipalities in Baja California Sur, which further aggravates both conservation and development concerns.

This chapter addresses local residents' perceptions on adaptation to climate change in REBIVI and offers insight on how biodiversity can lead to community welfare in this NPA. After this introduction, the chapter is organized as follows. The first section refers to the relevance of community participation regarding conservation, especially in a context of climate change, and focuses on methodologically grounded proposals that strengthen adaptation practices in vulnerable regions. The second part presents an overview of the challenges and sources of climate change vulnerability in REBIVI. A third section reviews the results from the workshops carried out in REBIVI with local producers and community representatives during 2017, which involved the scientific community, decision-makers, and rural communities to identify adaptation measures to reduce ecosystem and human vulnerability. A fourth part advances three examples of economic diversification as adaptation that also serve as biodiversity conservation mechanisms: whale watching, bighorn sheep hunting, and mangrove recovery. A final section presents some concluding thoughts and recommendations to advance the notion that actively promoting alternative economic and social ways to relate to nature can contribute both to conservation and community welfare.

18.2 Community in Conservation and Adaptation to Climate Change

Social participation is essential for biodiversity conservation and this is particularly clear in climate change conditions. The Intergovernmental Panel on Climate Change (IPCC) defines *adaptation* in human systems "as the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities" (IPCC 2012:5). Moreover, the IPCC underlined the argument that adaptation is imperative in order to address impacts resulting from the warming due to past emissions. Thus, since adaptation plays an important role in conservation, an integrated ecosystem-community approach is needed to pursue effective conservation strategies.

Ecosystem-based adaptation (EbA) is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change (Jimenez Hernández 2016; CBD 2015). As one of the possible elements of an overall adaptation strategy, ecosystem-based adaptation uses sustainable management, conservation, and restoration of ecosystems to provide services that enable people to adapt to the impacts of climate change. It aims to maintain and increase resilience and reduce the vulnerability of ecosystems and people that are confronted with the adverse effects of climate change.

EbA can generate significant social, economic, and cultural co-benefits, contribute to the conservation of biodiversity, and build on the traditional knowledge and practices of indigenous peoples and local communities—including the important role of women as custodians of local knowledge. In addition, healthy, well-managed ecosystems have climate change mitigation potential, for example, through the sequestration and storage of carbon in healthy forests, wetlands, and coastal ecosystems (GIZ 2016).

Community-based adaptation (CbA) has been defined as "a community-led process, based on communities' priorities, needs, knowledge and capacities, which should empower people to plan for and cope with the impacts of climate change" (Dodman and Mitlin 2013). It refers to an evolving yet distinct set of principles and practices that consistently target the most vulnerable populations and focus on activities with the greatest direct impact (Girot et al. 2016). This targeting and focusing, embedded in participatory situational analysis and action-planning processes, distinguishes it from development "business-as-usual" (Wamsler et al. 2016), which is often top-down and does not focus on the most vulnerable.

Adaptation strategies are generated through participatory processes that build on existing cultural norms and address the underlying causes of poverty that render some people especially vulnerable to the impacts of climate change. Influenced by this notion, the Global Environmental Facility Trust Fund and the United Nations Development Programme financed climate change adaptation programs (CCAP) for NPAs, which are derived from the Global Resilience Project. This project aims to reduce the direct and indirect adverse impacts of climate change on globally important biodiversity and human communities.

In Mexico, the project additionally sought to consolidate the institutional framework to implement the objectives of the Strengthening Management Effectiveness and Resilience of Protected Areas to Safeguard Biodiversity Threatened by Climate Change project (Resilience Project). Behind this was the recognition that a precautionary approach was in order to address the threats posited by climate change to the protected area system. In this context, it is important to increase the preparedness of NPA authorities and other stakeholders to address such a challenge (GEF 2012).

Such effort implies a prioritization of adaptation measures to climate change according to a multicriteria analysis of the adaptation measures of the Strategic Adaptive Axes as a support tool in the decision-making process (Zorrilla and Kuhlmann 2015). Multicriteria analysis is used to facilitate decision-making, so that different or even contradictory points of view may intervene. This is especially useful in planning, because it allows integrating different criteria in a single framework of analysis, according to the intervention of the participants.

Part of the information in this chapter results from the development of REBIVI's climate change adaptation program (CCAP-REBIVI) (Ivanova 2017), which was financed during 2016–2017 by the United Nations Environment Programme through Mexico's National Commission of Protected Natural Areas. Seven participatory community workshops (PKW) were held in January, February, and April 2017 with representatives from seven communities selected according to their population size, economic relevance, and geographical location. These representatives were Guerrero Negro, Vizcaíno (Villa Alberto Alvarado), San Francisco de la Sierra, San Ignacio, Santa Rosalía, Punta Abreojos, and Bahía Asunción.

The objective of the workshops was to gather the observations and comments of REBIVI inhabitants to enrich and further specify the strategies and lines of action of each Strategic Adaptive Axis by social groups, main stakeholders, and government agencies that would be responsible for their implementation and follow-up (Zorrilla and Kuhlmann 2015). In addition, as part of the PKW activities, the participants prioritized the actions of each Strategic Adaptive Axis based on a multicriteria analysis. Representatives from the municipal, state, and federal levels of government, nongovernmental organizations, community members and producer associations (ranchers, fishermen, farmers), and educational institutions participated in this exercise.

Workshop attendees were organized into five working groups, each with a facilitator (member of the research team) and a rapporteur: (a) water, (b) fisheries and biodiversity, (c) agriculture and livestock, (d) tourism, and (e) environmental education and research. Those Strategic Adaptive Axes had been previously defined in meetings of the research team with public officials of REBIVI and the Natural Protected Area Commission (which is in charge of the Resilience Project in Mexico). After the facilitator of each thematic group presented the work dynamics, participants were asked to write each idea or piece of information on a sheet of paper, from which the facilitator synthesized the information (eliminating repetitions). This exercise resulted in the creation of adaptation measures for each strategic sector. The discussion took place in two stages:

(a) Stage I. Assessment of climate change impact and identification of adaptation measures

At this stage, the impacts of climate change were identified by the assistants (e.g., drought, flooding, sea level rise, etc.). Then the level of each impact was ranked between 0 and 3 (0, no impact; 1, minimal impact; 2, considerable impact; 3, high impact). Then the consequences of the impact were defined (e.g., drought affects crops, sea level rise affects the coastal infrastructure, etc.). Next, participants defined the most appropriate adaptation strategies according to each impact. Once the adaptation strategies were formulated, there was discussion about whether or not any governmental institutions or civil society organizations received support for their implementation (e.g., financing, capacity building, and environmental education).

(b) Stage II. Prioritization of adaptation measures identified in stage I

The prioritization was performed according to the multicriteria methodology. The PKW participants discussed the following six criteria, ranking each of them from 0 to 3:

- Importance for the community
- Contribution to conservation
- Care for vulnerable population
- Resilience enforcement
- Community participation
- Institutional support (government and/or civil society organizations)

Then, each group of answers was discussed. Subsequently, the ideas were debated until consensus and possible solutions to the problem were identified. The results of these workshops are presented below, in the third section.

18.3 Livelihood Impacts of Climate Change in Mexico's El Vizcaíno Biosphere Reserve

In the region covered by REBIVI, three areas with different characteristics can be identified. The first corresponds to the sierras, the second to the plains that make up the basins of El Vizcaíno, and the third to the area of coastal lagoons, which exhibit high rates of biodiversity and conservation. Primary economic activities form the basis of community life in REBIVI; however, production patterns are far from homogeneous insofar as high-tech agriculture coexists with subsistence agriculture and livestock. In addition, small-scale coastal fisheries differ from export-oriented high-value fisheries, such as abalone and lobster, which are produced by fisheries cooperative societies. Further, federal government co-investment with the Mitsubishi Corporation in open-air salt mining makes Guerrero Negro, and thus REBIVI, one of the most important salt producers in the world, exporting over eight tons of salt per year.

Along with the production of salt, fishing, and alternative tourism (mostly derived from whale watching and hunting), agriculture is one of the most important economically productive activities carried out in this NPA. The municipality of Mulegé is the second most important agricultural region of Baja California Sur, and most agricultural areas are located in REBIVI (where agriculture is currently allowed in the portion identified as "area of sustainable use of natural resources"). This zone coincides with the lowlands, since most of the existing mountain ranges in the NPA are considered "restricted use zones" (INE-SEMARNAT 2000).

Considering the value of its production, Mulegé is the second agricultural center of BCS, after the municipality Comondú. Of a total of 115 companies or agricultural fields in the state in 2015, 22.61% are located in the municipality of Mulegé. Most of the 27 agricultural companies that operate in the REBIVI's buffer zone and in the subzone of sustainable use of natural resources rent land to ejidos.[1] In general, those firms operate with greenhouses or some type of protected agriculture. Production conditions related to favorable climate, soil (López Méndez et al. 2013), and sanitary conditions, as well as closeness to the United States' market, among other factors, make this type of production highly cost-efficient. It is also cost-efficient because the limiting resource, water, is relatively inexpensive.

Almost all El Vizcaíno agricultural valley surface is devoted to horticulture, with the exception of 288 ha that are destined for the cultivation of fig trees in Ejido Díaz Ordaz. Fig production is exported almost entirely to Hong Kong and Korea. The yield of fig trees begins to show a downward trend (GBCS 2016a, b). Agriculture in the municipality of Mulegé is highly industrialized, leading to a profitability of approximately 500 thousand pesos per hectare (or seven times more than any other agricultural region in the state). This high value of agricultural production places Mulegé, and consequently REBIVI, as the second most important agricultural region in the state with 23.8% or 50 million dollars in the 2013–2014 agricultural cycle.

For the 2014–2015 agricultural cycle, the most important production in the municipality and in REBIVI was vegetables, followed by organic vegetables and fruits, the latter with a higher value per volume produced. Of vegetables, the most important products are tomatoes, which contribute 91.94% and 85.25% of that section in the 2014 and 2015 cycles, respectively, and chilis with 7.98% and 13.81%, in each case (GBCS 2016b). However, BCS has experienced examples of water overexploitation from agriculture in other regions (such as the Santo Domingo

[1] Ejido is a form of land tenure in Mexico that combines communal ownership with individual use. Changes to the ejido system in the early 1990s allowed the privatization and sale of ejido land under the argument this would address problems related to the lack of productivity and farmer impoverishment; yet, with some exceptions and despite their great productive potential, ejido members face increasing challenges related to low investment, clientelism, poverty, and migration, among others. For an updated ejido situation in Mexico, see Morett-Sánchez and Cosío-Ruiz (2017).

valley), and the abovementioned level and patterns of production place heavy stress on water availability and quality in REBIVI, a concern shared by local communities in coastal and valley areas.

According to the most recent data (2015), the municipality of Mulegé comprises 43% of the state surface and a population barely above 67,000 inhabitants (or 8.7% of the state's total). This translates to a density of 2.1 inhabitants per square kilometer, which is lower than the state's average density (10 in./km^2) and far from the national average (61 in./km^2). Five localities hold most of the population: Guerrero Negro, Santa Rosalía (site to the municipality's political powers), Villa A.A.A. Arámburo (or Vizcaíno), H. Mulegé, and Bahía Tortugas. The average level of education in the municipality of Mulegé is 7.9 years, the lowest in the state. In addition, although the municipality is ranked with a low level of marginalization at the national level, it has the highest in the state: nearly 30% of people who are 15 or older have not completed primary education; 32% lived in overcrowded households; and 34% did not earn enough to escape poverty (GBCS 2015).

Most localities are isolated among themselves and also in relation to La Paz, the state capital, which is 780 km away from Guerrero Negro (the population center that borders to the north with the state of Baja California). The long and deserted transpeninsular highway, which ends in the Mexico-United States border, connects the Mulegé's most populated towns and cities, but dirt roads are the only means to access the most remote areas. Although this inhibits human interactions, it also favors ecosystem conservation—except in those areas where water overexploitation and scarcity have become an issue.

Employment in agricultural activities is not included in the economic censuses although its importance in demographic and social terms is recognized; this contrasts with fisheries, whose level of occupation is relatively even as shown by the low number of inhabitants in REBIVI's coastal areas. The growth of agricultural activities has spurred new population centers composed of migrant communities, especially from the states of Baja California, Oaxaca, Sinaloa, Guerrero, and Veracruz. In this way, about a quarter of population in Mulegé is settled in eminently agricultural communities (Ibid: 7).

When using greenhouses, the most productive season is extended up to 8 months. The number of employed persons (day laborers) varies, thus fostering a floating population of large proportions. Baja California Sur's migrant agricultural population, which is drawn from mostly indigenous communities in southern Mexico, was estimated at approximately 25,000 in 2015. These workers receive no labor benefits. Twenty percent were subcontracted by intermediaries who charge the employer a daily quota for each worker, while 80% were workers who lived almost permanently in the camps owned by agro-export companies. Approximately half of those migrant day laborers were located in Mulegé (BCS Noticias 2014; UABCS 2015). Considering that marginalization and poverty greatly exacerbate human vulnerability and ecosystem deterioration, the need for more sustainable models of production is evident in REBIVI.

18.3.1 Threats to the Primary Sector of the Economy in REBIVI Due to Climate Change

Fishing is highly relevant for the coastal communities in REBIVI. In spite of the relatively low number of inhabitants, these communities greatly contribute to the economy of Mulegé. Changes in temperature and ocean acidification have modified fish and marine resource populations, thus altering patterns of production in BCS (Ivanova and Gámez 2012). Particularly along the Pacific coast, revenues from exporting highly priced products (and a more entrepreneurial approach) have resulted in the development of highly qualified people who have the skills to monitor not just marine conditions but also markets and processes related to pursuing economic alternatives and business opportunities.

However, as in relation to agriculture, the fishing community is heterogeneous, and even those members that are economically advanced face environmental, social, and economic challenges. Some fishing cooperatives in REBIVI have developed means to adapt to the changing environment and have started aquaculture initiatives so they are not entirely dependent on climate variations. In other cases, such as in Punta Abreojos and La Bocana, a timid but informed incursion in tourism is underway. Reconversion to or income complementation with whale watching tourism—as in Laguna Ojo de Liebre and Laguna San Ignacio—has meant an improvement in many locals' conditions, as developed below, since whale populations are abundant (Urbán et al. 2010). However, sea level rise and storms endanger households, along with fishing and social infrastructure. This makes it imperative to develop ways to cope with extreme events and reduce risks associated to climate change.

Many of the extensions identified as areas of sustainable use of natural resources are located in the central part of the peninsula. Being away from the coasts, those areas would not be so exposed to the effects of sea level rise. However, there will be impacts to agriculture due to other climate change effects, such as droughts and rainfall pattern variations. In addition, in the agricultural colonies located in the Reserve, social, health, and human rights conditions are deficient (Sánchez 2014; Molina 2011), which increase the vulnerability of social groups such as day laborers, on whom agricultural production is based. These aspects can be aggravated without an adequate prevention that includes comprehensive multidisciplinary programs.

Activities that entirely depend on water, such as agriculture, are among the most vulnerable to climate variations (Magaña et al. 2012). In a scenario of climate change, one of the possible effects in arid regions is that droughts last longer. Temperature increase in Mexico's arid regions can cause the availability of water to decrease up to 30% due to a higher evapotranspiration, a condition that would lead to a large part of the vegetation to a state of hydric stress. In most of the Reserve, an increase of less than 1 °C is forecast in the coming years. However, from 2045 to 2069, temperatures are expected to rise throughout the region (RCP 4.5) and higher than 4 °C in a RCP 8.5 scenario in some of the agricultural production areas (the central plains, to the west of Marasal and Ejido G. Díaz Ordaz), as well as in the entire eastern part of the sierra. In general, a decrease in rainfall is expected throughout the region, especially in the central plains, which will become more arid (Ivanova 2017).

Under these conditions, increasing crop areas in REBIVI would create a complex situation, even if the availability of water remains stable. Mexican legislation established an extraction limit of 250 million cubic meters or mm^3 per well, equivalent to the irrigation of 100 ha; in Vizcaíno, the extraction was 60 L per second or 60 ha of irrigation. However, water scarcity conditions led to the establishment of an extraction limit of 175 million cubic meters for irrigation, which gave way to high-tech irrigation to maintain the same cultivated area. Currently, the agricultural areas of Mulegé have an extraction of 75 mm3 of drip irrigation that covers an area of 120 ha (Ivanova 2017).

As in the case of BCS, REBIVI is a natural greenhouse that offers unbeatable conditions for the production of vegetables. This includes soil conditions that result in high-quality cultivated products, high demand from foreign—especially American—markets, the consequent availability to and from the foreign investment, climatic conditions that offer stability with respect to temperature variations, and a geographic location that favors the absence of pests (López Méndez et al. 2013). The current high price of vegetables in the international market does not suggest the need for productive reconversion, at least not in the short term, so that the exacerbation of climate conditions will imply a greater demand for this resource. Another likely threat in this scenario is the higher incidence of pests. In recent times only small areas of agricultural production have been affected, but this situation could vary due to the effects of climate change (SAGARPA 2016).

Indirectly, social phenomena such as migration, marginalization, and gender inequality will undoubtedly increase in a climate change scenario and will probably have negative effects on local communities. In addition to the threat from climate change, stress on economic activities will likely result in the displacement, deportation, and relocation of migrants that can undoubtedly cause greater pressures for conservation, particularly in a climate change scenario. Women day laborers, in spite of harvesting just like men, generally have lower incomes and other family and social responsibilities and roles, since under conditions of marginalization, it is usually their responsibility to carry water, prepare food, and take care of their children and work cleaning (Sánchez 2014). All of the above activities require water and, faced with the threat of less availability of this vital liquid, will undoubtedly suffer more severely the effects of various phenomena.

18.4 Community Perceptions Toward Climate Change in El Vizcaíno Biosphere Reserve

There was no precise definition in the workshops by the participants regarding priority sites for conservation in REBIVI although, in general, concern for flora and wild fauna was expressed. In Guerrero Negro, attendees showed awareness about the existence of cave painting conservation initiatives, but this was primary in relation to a sense that the benefits of this conservation were not distributed sufficiently. Potential for exploitation of palm trees (*Washingtonia robusta*) is recognized. Regarding priority species for conservation, the peninsular pronghorn was highlighted, much to the appreciation of those who participated in the workshop, because it does not receive sufficient support in comparison with livestock and agriculture.

In Guerrero Negro, the most important activity is open-pit salt mining and services. However, due to the proximity to the town of Vizcaíno, where there is an extensive agro-export activity, there is a marked recognition of the environmental problems that this type of agriculture represents in a desert region such as REBIVI. Most of the families have their personal crops for family consumption, but they recognize the importance of integrating the communities' needs in the hydraulic works. They also attached importance to the effective regulation of sanitary conditions to prevent the introduction of pests that result from improper production practices.

During the discussion, participants in the workshop highlighted their interest in learning more about the effects and remediation measures in a climate change context, as well as access to technological improvements and changing crop patterns. The incidence of extreme temperatures is a cause of affliction, because crops are lost with frost, and more water is lost due to having to replant them. In this sense, it is worth noting open manifestations regarding timely and reliable information availability on climate and water quality, as well as developing research with a view to other types of crops and/or products with greater added value. The elements of definition and prioritization of adaptation measures in the workshop were, in order of importance, the scarcity and poor quality of water, the appearance of pests, drought, and extreme temperatures. As in Vizcaíno-San Francisco de la Sierra, technological improvement, training, and climate information were prominent elements as adaptation measures, but greater emphasis was placed on the need for producers to be better organized to jointly promote the water saving, as well as access to credits.

In Vizcaíno, the workshop was held with residents of Vizcaíno and San Francisco de la Sierra. The comments varied by the influence of the origin of the participants: agricultural those of the first and ranchers those of the second site. Considering that the planting in the Vizcaíno area comes from the extraction of the aquifers, the lack of rain or the greater heat automatically implies a greater use of water. Thus, the elements of greatest impact were the appearance of pests and diseases, drought, increased solar radiation, and frost. Interestingly, the presence of rains during the hurricane season (summer-fall) causes concern because they produce erosion and are a vector for diseases. One element to point out is that sprinkler irrigation is in place and workshop participants stressed the need to improve irrigation systems to make better use of water.

The town of Vizcaíno depends on the promotion of extensive agriculture for export to the United States; the largest proportion of agricultural activity in the Reserve is concentrated in that area. This type of agriculture has promoted very rapid economic growth due to the presence of agro-export companies in Vizcaíno, subsidiaries of parent companies based in states such as Baja California and Sinaloa, which have a high level of investment by foreigners. The sowing periods are, on the one hand, from January to June and, on the other, from August to December. These agricultural cycles determine the flows of the population, to the extent that there is a contingent of laborers from other states of the country that is employed in agriculture. Thus, the population is made up of inhabitants who have been settled there for a few decades, by a large floating population and by a more recent wave of people who settle on the site more permanently. The population increase linked to agricultural growth causes environmental problems due to the lack of drainage and proper handling of rubbish, since there are no adequate sites for the management of the population's waste, nor of the residues of the agricultural fields (plastics, fertilizers, etc.).

Day laborers have a significant economic impact in the area. When harvest season arrives, the sales of local businesses increase significantly. On the other hand, in terms of income, the ranchers earn between 8 and 10 thousand pesos a month in total, which, after expenses, are reduced to about 4 thousand; they do not have a close relationship with agro-export companies. Meanwhile, ejido members receive a more stable and higher income (10 thousand pesos per month) from Exportadora de Sal, S.A., the salt mining company. A prominent element noted in the workshop was the absence of social and economic conditions for young people to return or stay in Vizcaíno and surrounding areas. Additionally, although groups from different cultural origins shape Vizcaíno, social programs to promote cultural awareness and understanding are scarce, and attachment to the community is not encouraged.

Other issues in REBIVI relate to bad grazing practices in open fields, which are worsened by droughts, produce erosion, and lead to social disputes. Workshop participants argued that if regulations were correctly applied, those problems would be avoided. Due to extreme temperatures (heat and frost), export producers make use of more pesticides, but this means not complying with export-related regulations and increased losses (sunburn and frost damage agricultural production and make sales in the US market unviable). Growers complained that the absence of rain increased pests that attack crops, which became food sites given the scarcity of native vegetation. Also, since REVIBI is a protected area, regulations prevent locals from harvesting palm tree leaves in ravine areas that could be sold for thatching and could help prevent vegetation fires; thus, without a proper management program, reforestation programs were questioned.

One element that was highlighted was the need for the authorities to train people regarding what they can do and how to do it within REBIVI. Because of their lack of knowledge, people misuse resources or simply sell their rights to land and water. Although the issue is not directly related to the effects of climate change, the progressive sale of water rights to agro-exporting companies by farmers—in the absence of other economic opportunities and a lack of a long-term vision—is a general concern. This leads to their impoverishment and, on the environmental side, to erosion, water scarcity, and soil pollution as the agricultural frontier and production volumes are expanded.

Regarding the combined EbA and CbA approach applied during the field study and consulting, a combination of activities was prioritized by REBIVI community members, as follows:

- Promote livelihood resilience (productive activities diversification):
  - Develop ecotourism activities that could generate income for the community, while protecting biodiversity.
  - Promote aquaculture or seek new fishery resources.
  - Use hardier seed varieties and high-tech irrigation.
- Conserve or restore coastal wetlands, mangrove forests, and/or woodlands.
- Take a holistic approach to watershed management.
- Employ "natural solutions" to reduce hazards (e.g., protecting or restoring mangroves to reduce the risk of sea level rise and coast erosion).
- Minimize disaster risks and, thus, the impact of hazards, particularly on the most vulnerable groups and individuals.
- Strengthen local civil society and government institutions' capacities so that they can more effectively support communities and individual adaptation efforts.

Lastly, with the participation of local actors and decision-makers, on July 14, 2017, REBIVI's Scientific Subcommittee on Climate Change and Exotic Species prioritized and validated the actions agreed upon in the seven community workshops. This included consideration of issues such as the identification of monitoring strategies, conservation objectives, gender inclusion, and equity and women's empowerment. The final conclusion was that inclusive mechanisms of education, training, and access to better technologies could generate productive and economic conditions. Such changes could lead to greater access to training and the development of skills to improve general standards of living, as well as the empowerment of women through their inclusion in productive work and in making decisions about their own future.

As seen, EbA and CbA projects embrace activities that are both community- and ecosystem-focused. These commonalities are most apparent when they are put into practice. The following case studies illustrate some of the benefits of the combined appliance of EbA and CbA approach to adaptation and resilience building. These alternative activities, which have already been developed, enhance both livelihoods and ecosystem functionality in REBIVI and match results from the workshops. Ecosystem conservation and social welfare in REBIVI would undoubtedly benefit from developing more eco-friendly economic alternatives, increasing knowledge on climate change issues, and strengthening institutional and legal capacities to facilitate the implementation and monitoring of adaptation actions.

18.5 Economic Diversification as Adaptation and Biodiversity Conservation

As mentioned before, three experiences of economic exploitation of biodiversity are provided in this section: whale watching, mangrove reforestation, and bighorn sheep hunting. All of them are led by communities in REBIVI, thus setting examples of how conservation can be central to community adaptation and welfare.

18.5.1 Gray Whales

Laguna Ojo de Liebre (LOL) is located in the central part of the Baja California peninsula, in the Pacific Ocean. UNESCO inscribed LOL on the World Heritage list in 1993, and it is the breeding area for the gray whale (*Eschrichtius robustus*), which every year travels 9000 kilometers from the Bering and Chukchi seas in the Arctic to the coasts of the peninsula of Baja California. Among gray whale populations in the world, this one remains the healthiest and most abundant (Urbán et al. 2010) and can be closely observed and is friendly with humans. Ecotourism at Ejido Benito Juarez in LOL and by small and medium enterprises in Laguna San Ignacio (Fig. 18.1) has contributed to raising the living standards of the local population and has promoted environmental protection and minimum impact practices, in addition to providing environmental education to its visitors (Valle Padilla and Cariño Olvera 2010).

Fig. 18.1 Gray whale watching in Laguna Ojo de Liebre (Ekaterine Ramírez 2012)

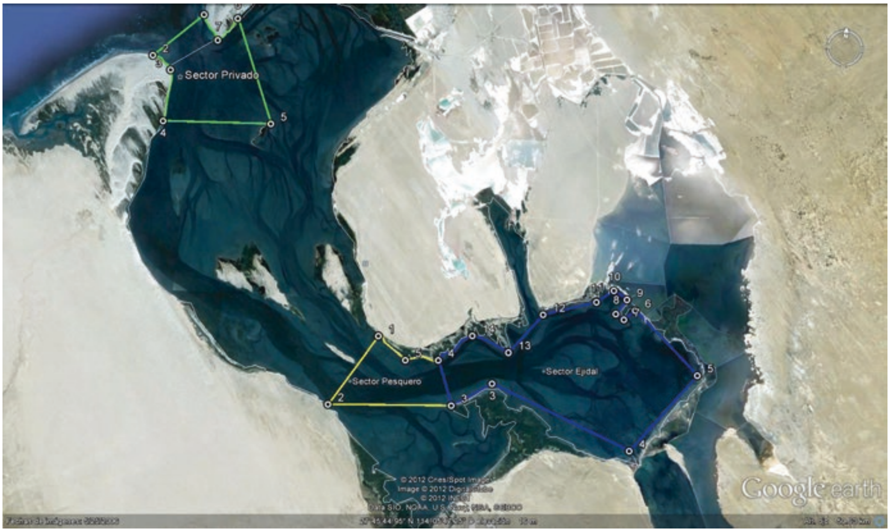

Fig. 18.2 Delimitation of Ejido Benito Juárez' gray whale watching area in LOL (in blue). (Adapted from Google-INEGI 2012)

Gray whale watching zones in LOL are pursued by private enterprises, fishing cooperatives, and ejido member sectors. The latter come from Ejido Benito Juárez, which is located 3 km off the federal highway by asphalt road and 17 km from Guerrero Negro city. Approximately 50 families live in Ejido Benito Juárez; their quality of life is good and income is enough to cover their needs. Agriculture used to be the main economic activity, and most families still have backyard gardens with fruit trees, vegetables, and magueys for their own consumption. In the past 12 years, they began to supplement their income mainly with gray whale tourism in LOL (Fig. 18.2).

Over time, this activity became their main source of income, enhancing not only their standard of living but also the ecosystem's conservation and the adaptation to climate change.[2] This has only been possible through collaboration and coordination in public, private, and social sectors, as well as cross-sectoral support and international cooperation. Moreover, as one community member stated: "to preserve biodiversity in the Reserve, support from the people who live in it is obviously needed." [3]

Ejido Benito Juárez is relatively new, and its members went through a peculiar process to become a community ecotourism company. The colonization in the Vizcaíno valley goes back to the end of the 1960s when, by presidential decree and

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[2] Ekaterine Ramirez-Ivanova's personal communication with Noé Alcalá Giménez and Emma Velázquez Alcalá by Ekaterine Ramírez-Ivanova, Centro de visitantes/Casa de la Ballena Mexicana, Laguna Ojo de Liebre, Guerrero Negro, Baja California Sur, February 12, 2012.

[3] Antonina Ivanova's personal communication with Celerino Montes, Taller Participativo Comunitario del proyecto "Programa de Adaptación al Cambio Climático de la REBIVI," Guerrero Negro, January 3, 2017.

according to agrarian reform legislation, land was made available to people from other regions in Mexico.[4] Settlers from Guanajuato, Jalisco, and Zacatecas founded Ejido Benito Juárez in 1971. Coming from a purely agricultural tradition, they found themselves in arid lands; ever since, water scarcity and climate change impacts have increased their agricultural activities' vulnerability.

REBIVI's Management Plan (INE-SEMARNAT 2000) explicitly regulates the priority local communities have in developing ecotourism. Although UNESCO lists LOL as a World Heritage Site, sustainable economic activities can be developed in REBIVI's buffer zone since 1988 (Ramírez et al. 2015). Therefore, during the whale-breeding season, all human activity is prohibited in the lagoons except for whale watching (ecotourism) and research activities (INE-SEMARNAT 2000).

Federal government institutions were crucial to devise conservation mechanisms and community participation. REBIVI officials helped promote ecotourism through meetings with community members to make them aware of the advantages of gray whale watching. Local inhabitants were not interested at first, but after several attempts they became convinced of the benefits of whale watching to increase their income.[5] Ecotourism also became a business opportunity for some private companies located in Guerrero Negro. Nowadays, both REBIVI officials and ejido residents deem this as an economically profitable activity, which meets the sustainability objectives emphasized by the management program of REBIVI and is a valuable tool for climate change adaptation.

18.5.2 Mangrove Recovery in Campo Delgadito

Campo Delgadito is located in the southern part of Laguna San Ignacio, in the longitude 113.059167 and latitude 26.608056. This REBIVI community is an example of conservation of some of the mangroves found further north in the Mexican Pacific. The inhabitants there are dedicated to traditional fishing, organized under cooperative ownership. There are three fishing production cooperatives (*Sociedades Cooperativas de Producción Pesquera*): Cooperativa Cadejé, September 19, and Mujeres del Delgadito. The first two are dedicated to the extraction of scales, ax callus, Pismo clam, and lobster.

Mangroves are of great importance for climate change adaptation and mitigation. They are trees or shrubs that develop in the intertidal (the area where waves break at high and low tides) and provide many environmental services (SEMARNAT 2012; Wildcoast 2014, 2016a). This ecosystem protects the coast from erosion by limiting the impact of sea level rise and is also a carbon sink that absorbs almost three times more carbon dioxide than green forests.

[4] Ekaterine Ramírez-Ivanova's personal communication with Irma González López and Celerino Montes, Dirección de la Reserva de la Biósfera El Vizcaíno, Guerrero Negro, BCS, February 10, 2012.

[5] Ekaterine Ramírez-Ivanova's personal communication with Irma González López and Celerino Montes, Dirección de la Reserva de la Biósfera El Vizcaíno, Guerrero Negro, BCS, February 10, 2012.

Fig. 18.3 Climate change effects on mangroves, Campo Delgadito (Antonina Ivanova 2017)

As fisheries are affected by changes in climate, overexploitation of resources, pollution, and bad practices, mangroves of Laguna San Ignacio are considered key to conservation and the locals' economy and food security (CONANP 2016). Mangroves play an important role in keeping water free of pollutants and reducing pressures from high temperatures (Wildcoast 2016b), and inhabitants of Campo Delgadito recognize that mangroves protect their community from hurricanes, storms, and floods. Fishermen get most of their products from the open sea, but they acknowledge that mangroves play an important role as food banks and protection sites for the species they capture: without mangroves fishing would not be possible, since mangroves protect both fish and shellfish.[6] However, in recent years, mangroves have been adversely affected by climate change (Bautista González 2014): In Campo Delgadito, a high mortality of white mangrove has recently been noted (Fig. 18.3), due to the proliferation of some species of algae that surrounds its roots and dries them.[7]

David Borbón and his family (see Fig. 18.4) have dedicated themselves to reforesting red mangroves by planting propagules (see Fig. 18.5) under natural conditions (without the use of greenhouses). The activity has been successful insofar as for the last 3 years, the area has been repopulated with 30,000 new plants and 10,000 more propagules were introduced during 2017. Also, a group of young people and women in the community permanently participate in cleaning new plants (Montaño

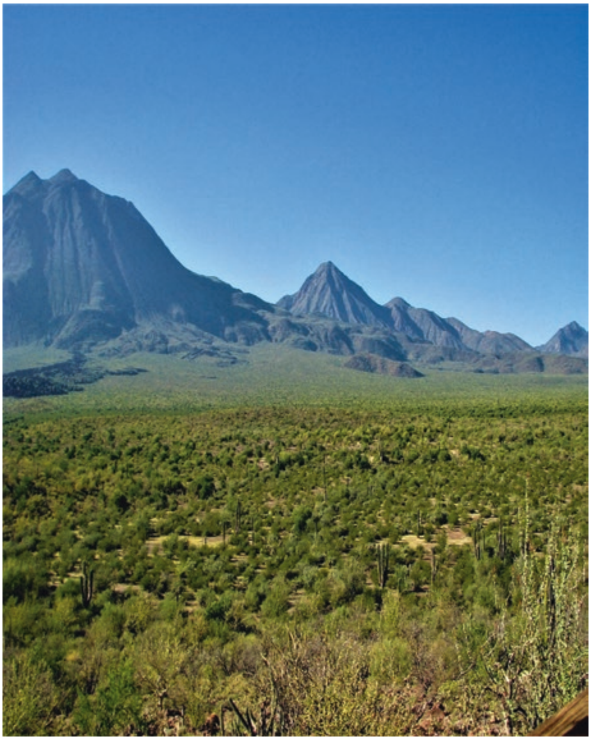
[6] Antonina Ivanova's personal communication with David Borbón Ramírez, Campo Delgadito, Laguna Ojo de Liebre, BCS, September 24, 2017.

[7] Antonina Ivanova's personal communication with David Borbón Ramírez, Campo Delgadito, Laguna Ojo de Liebre, BCS, September 24, 2017.

Fig. 18.4 David Borbón and his family, Campo Delgadito (Antonina Ivanova 2017)

Fig. 18.5 Growing mangrove propagules in Campo Delgadito (Antonina Ivanova 2017)

Fig. 18.6 Volcán de las Tres Vírgenes (Eduardo Juárez 2017)



2017), as well as in the monitoring and surveillance them; children have been invited to observe and engage in those activities. Thus, environmental education has been promoted at the community level, based on mangrove reforestation.

To further strengthen this activity, the Borbón family seeks to learn more about mangroves, strengthening ties between El Delgadito's community and research institutions. This unprecedented initiative could be strengthened by further support from government and civil society organizations and be disseminated as a successful example of community-based conservation of natural resources and environmental education.

18.5.3 Bighorn Sheep: Management Units for Wildlife Conservation at Ejido Bonfil

Another emblematic example of resource management in REBIVI is bighorn sheep (*Ovis canadensis weemsi*) hunting. The Official Mexican Standard (NOM) 059-ECOL-1994 considers this species as subject to special protection, and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) includes it in Appendix II. The largest distribution of bighorn sheep within the Reserve is located in 217,000 out of the 519,000 ha that make up Nuevo Centro de Población Ejidal Lic. Alfredo V. Bonfil (NCPE Bonfil), particularly in the area of Volcán de las Tres Vírgenes (Fig. 18.6) and the Reform sierra (INE-SEMARNAT 2000).

In 1995, NCPE Bonfil's community began the bighorn sheep hunting program from a Unit for the Conservation, Management and Sustainable Use of Wildlife (UMA Bonfil). The purpose was to build a mechanism that would allow, on the one hand, the generation of economic resources to improve the living conditions of the local population and, on the other, the development of self-sustaining practices in the long term. To this end, they implemented three measures based on the recognition that the future of cynegetic activity depends on better conservation practices. The first is monitoring and surveillance that involves REBIVI's staff and local inhabitants; the second is expressed in the habitat and wild sheep population management program; and the third integrates environmental education, both for UMA Bonfil administrators and hunters.

18.5.3.1 Resource Management and the Logistics of Hunting

The cynegetic activity begins with a helicopter monitoring NCPE Bonfil hunting zone every 3 years to determine the 8–9-year-old male population; this is deemed as old, since the average life of a sheep is 10 years.[8] Then, the Secretary of Environment and Natural Resources and the National Commission for the Knowledge and Use of Biodiversity issue the number of permits for the season. Authorized permits are offered at auctions usually held in the United States (Las Vegas and Sacramento). After the sale and reception of logistical information, staff from UMA Bonfil picks the hunters up at an agreed location, usually the airport of Loreto, BCS. From that moment, all costs are absorbed by the UMA administration.[9] UMA Bonfil also provides support for the migration process and firearm registration. Once the administrative requirements are completed, hunters are taken to the camp, where comfortable cabins and a restaurant with regional meals are provided. The hunter has 10 days to get his/her prize. Even if the objective has not been achieved, she/he loses the right granted by the permit and must buy a new permit at a future auction.

Hunting rates are very high. The expedition consists of approximately 12 people (backpackers, interpreter, guides, and cook), and on average a hunter gets his prey in 4 days. After locating the prey, the hunter is informed about the approximate score it has, which depends on the antlers taking's size (length and thickness). This aspect is key to the hunter because the higher the score, the better the piece's value. In addition, better-quality hunting pieces imply that future permit prices may

[8] Eduardo Juárez' personal communication with Zootechnical Engineer Carlos Enrique Zambrano Romero, head of special projects of Ejido Alfredo V. Bonfil, Baja California Sur, on October 23, 2017, at Tres Vírgenes UMA.

[9] Eduardo Juárez' personal communication with Francisco Javier Romero Juárez, sheep hunter and guide of Tres Vírgenes UMA, on November 22, 2017.

increase. The hunter is only interested in antlers and skins, which are later shipped abroad after basic treatment (salted leather). Since 1996 an average of four permits has been granted per season, which has generated about 3.5 million dollars during the 22-year length of the hunting program. At that time, there was an overall population of 100, and most recent census estimates (2014) count over 250 individuals. This has allowed the inhabitants of NCPE Bonfil to internalize a new way of understanding conservation and the use of their surrounding resources.

18.5.3.2 Conservation and Hunting

This resource management model has made bighorn cattle numbers rise and has generated resources to improve the economic conditions of community members. All the income obtained from the sale of the permits is invested in the community; once the operating expenses of the project have been deducted, 50% is used for conservation, and the remaining money to improve local social conditions. A trust manages the economic resources generated by the program, and all financial decisions are taken in the plenary session of a technical committee, formed by federal, state, municipal, and ejido authorities.

However, as in similar cases (Paterniti 2017), controversy surrounds trophy hunting. On the one hand, it is argued that hunting goes against the basic principles of conservation but, on the other hand, that it allows conservation of the general conditions of the ecosystem, strengthens the inhabitants' interrelationships and trophic networks, guarantees the conservation of bighorn sheep, and provides services for the survival of other species. In addition, community members argue that UMA Bonfil's surveillance keeps unregulated poachers away; additionally, given the economic benefits of hunting, cattle owners voluntary removed their flock from the areas of contact with bighorn sheep, avoiding competition for food and disease transmission.

Bighorn sheep hunting has been practiced in UMA Bonfil over the course of 22 years, while the wild population has remained balance (Fig. 18.7). So, it seems that conservation and trophy hunting can coexist, insofar as the financial resources generated from the hunting activity have improved this and other species' habitat, as well as the general living conditions of local inhabitants.

However, and despite this, there are areas of opportunity not yet explored:

- The discussion about hunting could be solved with the participation of conservation organizations that could pay for permits, but without actually going through with the actual hunting. This would avoid or at least reduce the cynegetic activity, favoring an ecological balance.
- The frequent conflicts of consanguinity of the species in small herds without contact with other populations could be solved with the professionalization of UMA Bonfil's members in bighorn sheep management and biology: (a) creating a sperm bank and exchanging semen with other centers, temporarily confining the females and performing artificial insemination with the exchanged semen,

Fig. 18.7 Bighorn sheep hunting visiting center in UMA Bonfil (Eduardo Juárez 2017)

and (b) expanding the population census not only to locate suitable males, but to have information on the juveniles and their development.

- The local community could diversify its economic activities still using the bighorn sheep, through the generation of products that could raise the level of knowledge on this species and, in general, on environmental education. One source of financing could be international foundations interested in the conservation of biodiversity and development of audiovisual and printed materials, for instance.

18.6 Conclusions

From January to April 2017, seven communities were included in a study to analyze their member's perceptions on climate change, community adaptation mechanisms, and how these factors affect conservation in the Mexican natural protected area Reserva de la Biosfera El Vizcaíno-REBIVI. The workshops included REBIVI's staff as well as government officials and representatives from social organizations. Five of those communities are on the state's mainland, Guerrero Negro, Vizcaíno, San Francisco de la Sierra, Santa Rosalía, and Ejido Alfredo V. Bonfil, where agriculture or livestock are the main economic activities. Two of these communities are placed on the coast, Bahía Abreojos and Bahía Asunción, and both are fishing communities. Economic activities in REBIVI are mainly agriculture, fisheries, open-air salt mining, and services related to attending the small urban populations in the area. Whale watching, cave painting tourism, and hunting have become a source of economic diversification for some communities, although they are still incipient in the area.

Agricultural activity in REBIVI is heterogeneous. On the one hand, intensive, industrialized export agriculture is performed in the Vizcaíno valley based on foreign investment and migrant laborers; this export targets the United States as the market for the fruits and vegetables harvested in REBIVI. A second segment, mostly formed by Alfredo V. Bonfil ejido members, exports dates and figs. Finally, backyard agriculture mainly for self-consumption predominates in the mountain areas. Regarding livestock, the production of cattle for milk and meat is marketed locally or is a means of subsistence for the population of small ranches distributed along the Reserve.

The concentration of agricultural activities in the Vizcaíno valley and Ejido V. Bonfil, as well as the dispersion of livestock activities in the mountain area in the context of the wide geographical extension of REBIVI, complicates efforts to determine rates of vulnerability in and for the Reserve. Thus, although the adverse effects of climate events, such as droughts and hurricanes, are common throughout REBIVI and make all producers vulnerable, the geographical position of the towns and productive activities makes a difference with respect to the degree of their impact; this is also influenced by the level of income and the real capacities of these populations to prevent or recover from such effects. Thus, climate change exacerbates vulnerabilities already present. For example, it can affect income as is the case of mountain rancher, or, alternatively, it can impact health as with the case of agricultural day laborers, who face extreme events in disadvantageous conditions.

Hurricanes, drought, pests and diseases, and extreme temperature (heat, frost) are the main sources of vulnerabilities and impacts based on the information from the workshops. In a region with high water stress, drought stands out as an element of vulnerability that affects the yields of intensive agricultural activity. However, considering that aquifers are the source and current production rhythms are not hindered, uncertainty (and vulnerability) is more general to all of the population of the Reserve given water shortage, as are the effects of this type of agriculture on the conditions and health of soil, air, and human and wildlife in REBIVI.

Regarding adaptation measures, better infrastructure and technology, research and training, and organization and awareness of production practices were advanced. Among the actions with most potential are the following: less conversion of forests to agriculture, the development of highly efficient agricultural practices, the selection of more specific crops for arid conditions, and a more efficient use of water. All are important aspects to consider in REBIVI to improve agricultural practices in a framework of environment conservation and to guarantee production and suitable living conditions for the local population in the long term.

In this sense, interinstitutional work is key. Currently, information that would be useful for making progress on challenging issues is dispersed in institutions and government agencies. It would be highly relevant to improve regulatory schemes based on (1) responsible public policy, (2) the participation of specialists from academic institutions, and (3) the development of an agricultural culture that includes technical elements in production and research on the social and economic dimension of agriculture. In this regard, there is a clear need to develop and promote more information to aid better government and individual decision-making, as well as to enforce existing regulations. Also, although most of the Mulegé municipality population lives inside REBIVI, the lack of knowledge about the ecosystem and value of this protected area was notorious. This makes it important to channel resources to REBIVI's staff to make their conservation programs known in the region.

Adaptation was the focus of the workshops, but mitigation measures in REVIBI to cope with the expected threats of climate change were also devised and included the application of more advanced technology to reduce greenhouse gas emissions, agrochemicals, and waste from agriculture; protection against erosion; integrated management and fire control practices; diseases and pests outbreak controls; and improvement of production practices. Conditions must be sought to stop the increase of agricultural land, based on the fact that the limiting factor is water supply, which in principle is not expected to increase. Soil maintenance and recovery, and reforestation activities to prevent the advance of agricultural borders, were proposed as well.

The wide territory covered by REBIVI and its low human population density make this protected area a valuable case study in terms of its potential for ecosystem conservation and bettering its inhabitants' quality of life. Workshops showed awareness of the problems communities face and some possible solutions to accomplish those goals. In that sense, successful examples of economic diversification as adaptation through a responsible exploitation of biodiversity have been pursued, and, yet, even those positive experiences face important challenges. This means that both human welfare and conservation need to be placed in the wider context in which economic growth models are put forward. It is also imperative to consider the vulnerability and heterogeneous capabilities community members have in order to better adapt to climate change and strengthen their capacities for action.

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Chapter 19
The Value of Ecotourism and Ecosystem Services in Espiritu Santo Island National Park, Mexico

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Abstract The concern for the health of marine protected areas (MPAs) has become evident since they are complex and highly related structures where interactions take place to different scales of space and time. From an economic perspective, their functions are to provide goods and services that improve human well-being and the economic condition. Normally the goods and services in MPA are not traded in the market and are subjected to externalities that affect ecosystems. Espiritu Santo Island National Park is located in the Gulf of California and is important for being a refuge, zone core, and protection of several attractive marine species for tourist development. The aim of this paper was to characterize the uses and expenses of tourists in the MPA and recognize the preferences of individuals using the travel cost method (TCM). Results indicate that a correlation between income, ecosystem quality, and frequency of visits indicates that marginal effects are statistically significant in ESI and is possible to increase the access fee quota without affecting the demand for visiting the MPA, increasing the financial income to support greater conservation efforts.

Keywords Ecosystem services · Value · Tourism · MPA · Coastal ecosystems

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19.1 Introduction

Tourism is one of the largest global industries and is a recognized growing market that is focusing around pristine natural environments such as coastal and marine areas. According to Baveye et al. (2013), marine protected areas (MPAs[1]) are established worldwide to maintain biodiversity, ecosystem functions, and flow services provided by the ecosystems; nowadays MPAs are attracting interest from foreign visitors, as well as local residents, increasing economic benefits for local and foreign service providers which supply the means to visit the MPA and practice recreational activities such as scuba diving, snorkeling, kayaking, or watching the ecosystems which host different marine species (Polasky et al. 2012).

In Mexico, tourism in MPA has increased the number of visitors; according to the National Commission of Natural Protected Areas, between 2002 and 2005, the number of visitors reached 20 million, generating an economic income of approximately $5 billion Mexican pesos (CONANP 2000). Currently, it is considered that 85 of the 177 natural protected areas in Mexico have the potential to support activities related to sustainable tourism (Arizpe et al. 2017).

According to Daily (1997), ecosystem services (ES) are defined as the visible and invisible benefits that humans receive from the ecosystem that can be in a direct or in an indirect way. Many studies worldwide have demonstrated the importance ES provide in monetary terms to the tourism sector such as MA (2005), TEEB (2010), Boyd and Banzhaf (2007), Fisher et al. (2008), Ostrom (1999), Barbier (2011), DEFRA (2007), and UNEP (2006).

Regardless tourism can benefit local communities and MPA through revenue generation and employment (Sala and Knowlton 2006). Tourism can affect in a negative way the MPA resources through some negative factors that destroy the habitat, disturb wildlife, impact the water quality, and threaten communities by overdevelopment, crowding, and disruption of local culture (Turner 2010).

Baja California Sur (BCS) is a Mexican coastal state and has an area of 73,475 km^2 (28,369 mi^2) or 3.57% of the landmass of Mexico and comprises the southern half of the Baja California Peninsula. In this state and near the capital, there is an MPA, the Espiritu Santo Island National Park (ESI), which is located between 24° 24′ and 24° 36′ north latitude and 110° 18′ and 110° 27′ west longitude, separated from the Pichilingue Peninsula by the San Lorenzo Canal, approximately 8 km wide, and is part of the eastern limits of the Bay of La Paz (Fig. 19.1). The ESI is one of the main tourist attractions of La Paz Bay; this island is visited due to the variety of recreational activities that could be performed in it (CONANP-SEMARNAT 2006).

The ESI attracts tourist from all over the world because of its natural resources and pristine ecosystems; ESI also provides economic benefits through tourism to the local community, and according to CONANP (2014), the ESI receives around 16,900 tourists each year generating a very significant income (Figs. 19.2 and 19.3).

[1] This acronym is used indistinctly for singular and plural in the manuscript.

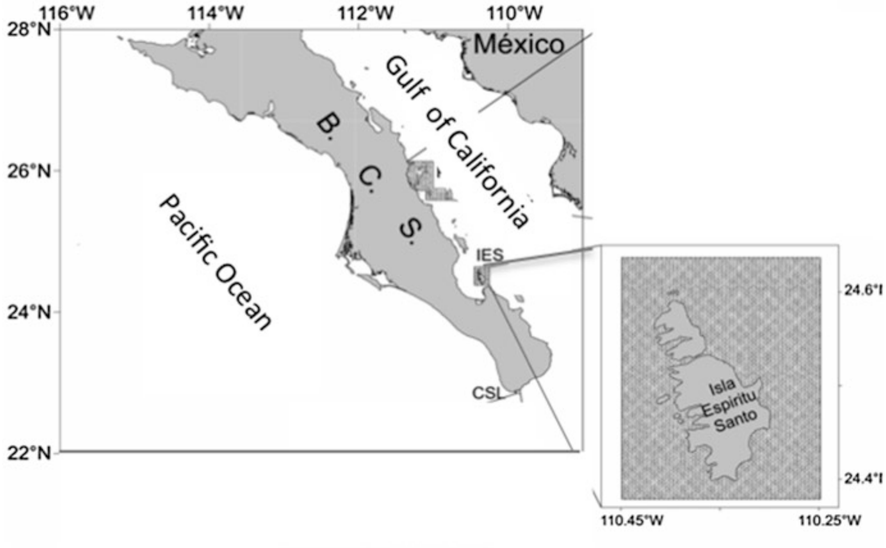


Fig. 19.1 Area of study (own elaboration)

Fig. 19.2 Espiritu Santo Island. (Reproduced from León-García 2016. Copyright 2016 by Mariana León García)

Fig. 19.3 Tijereta, *Fregata magnificens.* (Reproduced from León-García 2016. Copyright 2016 by Mariana León García)

This chapter is presented in three sections: the first one presents a theoretical framework about valuation, which remarks the total economic value (TEV) of ES, the second one integrates a participatory framework to value marine and coastal ecosystem services adapted from Lopes and Videira (2013), and the third section presents an analysis of visitors to the MPA through the travel cost method using surveys which were focused on the different recreational activities practiced by visitors, the amount visitors pay to visit ESI, the level of satisfaction they have after visiting the MPA, the perception in the ecosystem quality and education level, means of transportation, and knowledge about the MPA.

19.2 Why Is It Important to Recognize the Value of MPA?

Natural resources provide different marketable goods; they for sure have a monetary value in the markets. Examples of these products are fish, agricultural products, honey, timber, and some others (Failler et al. 2015). Different kinds of products are those ones that cannot be traded in the market as tourism benefits and cultural services provided by natural resources (Straton 2006).

Until now, scientists, societies, enterprises, and in general some stakeholders around the world are considering the important function that the visible and invisible benefits of ecosystem provide to human society through ecological, sociocultural, and economic goods and services (Costanza et al. 1997). In order to remark these benefits, expressing the value in monetary units helps policy makers to demonstrate that the loss or absence of ES will affect in many ways biodiversity and as a consequence all living beings (Crossman and Bryan 2009).

Economic analysis is needed in ecological assessment to provide a measure of economic performance in the past and a measure of a potential economic impact of changes in both ecological and economic systems (Costanza et al. 2014). Valuation of the worth of resource and ecological assets in monetary terms is necessary to provide a measure common to the rest of the economic system (CIESM 2008). Economic analysis provides a measure of economic feasibility in various alterations that are viable in ecological terms (Gómez-Baggethun and de Groot 2010).

Decisions in natural and environmental resources, both in public and private sectors, are made on the basis of economic feasibility, among many other considerations (Crain et al. 2009). Financial feasibility is usually the first to be considered, because proposed management activities require a budget that must be justified in economic terms (Balmford et al. 2008).

19.2.1 Economic Framework of Marine and Coastal Ecosystems

Marine and coastal ecosystems in economic aspects provide many elements for TEV since ecosystem functions allow the use of values that can be used directly such as food or ornamental products and indirect values such as climate regulation, water regulation, coastal protection, and recreational opportunities (Bateman et al. 2011). For the non use values are important to mention that bequest values and existence values may increase an individual's welfare derived from the knowledge that biodiversity is protected (Pimm et al. 1995).

According to Ibáñez (2016), coastal areas play a strategic role in many countries around the globe, due to the variety of ES provided by these areas. Worldwide, it has been determined that coastal areas hold between 40% and 70% of the estimated value of the planet's ecosystems (Farley and Costanza 2010). Marine and coastal ecosystems are considered relevant since they provide the opportunity to develop recreational and cultural activities for many people, and in order to practice the recreational activities, ecosystems should be healthy and clean to maintain the visibility that is needed to practice some sports and marine recreational activities such as swimming, scuba diving, and some others (Wincler 2006).

In this context, coastal areas are particularly relevant because of their social, ecological, economic, and even cultural values, a main reason why countries all over the world take advantage and use their touristic potential. Mexico has 11, 122 km of coastline, which provides diverse ES; among all these services, recreational services have been considered as one of the main services which extend the attractions that generate income for the coastal communities (Martinez et al. 2007).

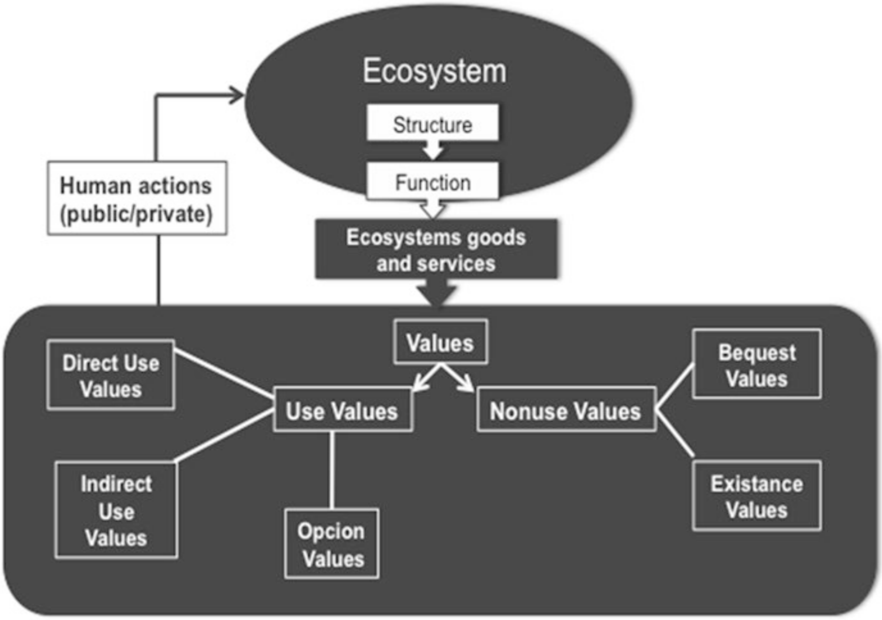


Fig. 19.4 Value of marine ecosystems. (Source Barbier 2006)

According to De Groot et al. (2002), for many ES users protect current biodiversity, and biological recourses are vital for both the current and next generation to enjoy, and a way to do it is through the assessment of contribution of biodiversity to people's welfare which should ideally be considered within the TEV framework (Fig. 19.4).

The economic valuation of ES is based on the theory of total economic value of Pearce and Turner (1990). The framework develop a strong background to define the total economic value (TEV) of the ES damages integrating two main elements: these elements are classified as use values (UV), which include direct use values (DUV) related to the recreational benefits and indirect use values (IUV) related to non-direct ecosystem benefits (Bateman et al. 2002).

The second element is the nonuse value (NUV), which includes the preferences of individuals who do not intend to use; generally the values of nonuse are associated with both one or more final services and to the structure of the ecosystem (Smith 1988). Within NUV, there is the option value (OV), a value that is given by the possibility of using it in the future (e.g., preserving the option of visiting a natural space). The existing value (EV) is based on the satisfaction of the people, the experience of knowing that there are certain ecosystem services for themselves and for others. The bequest value (BV), which is the willingness to pay to maintain intact ecosystems for the benefit of current and future generations, is associated with intergenerational equity (Turner et al. 2007).

TEV is a tool to explore the types of values that can be associated with each ecosystem service; it helps to determine the valuation methods necessary to capture these values. Although economic valuation can be criticized from many angles, the main strength of it is that it can inform policy making with democratic choices made by citizens in the form of monetary intensities. The units of these intensities are then consistent with the monetary units of cost and benefit indicators that tend to dominate in public and political decision-making. Developing valuation analyses and involving different stakeholder groups, to account for the fact that stakeholders may hold distinct values, which in turn can have a unique relationship with certain characteristics of them (Van den Bergh 2006).

19.2.2 Valuing Ecosystem Services and Its Bundles in MPAs

According to Martinez (2005), one of the key aspects on the discussion of marine and coastal services valuation is the relationship that exists between them, which increases the complexity and requires a more detailed analysis and management. In MPA, sectors such as tourism, fisheries, and services providers cause conflicts since these activities are not regulated enough because of the lack of budget and surveillance (Perrings 2006). In Mexico, specifically in Baja California Sur, tourism is the main economic source for coastal communities and is positive because it brings benefits; however, planning and economic resources have been not enough, affecting natural capital, causing irreparable damage or high restoration cost (Smith 1988).

In Mexico, tourism activities and biodiversity are directly linked through the National Program of Tourism in Protected Areas (NPTPA) 2006–2012; this tool was designed by CONANP and the Secretary of Tourism (SECTUR), with support from other institutions, with the objective to contribute to conservation, through sustainable development and tourism, and thus maximize their benefits to local communities (CONANP 2007).

Slowly certain decisions have been made to follow and implement the management plans of MPA. Evolution of policies, laws, and decrees to protect marine and coastal ecosystems has diversified integrating the coastal communities and tourists as part of the development of valuation plans; however, there still occur cases where the undervaluation of ES affects decision-making and therefore the preservation of them (Bockstael and Mcconnell 2011). Nowadays there is no single indicator that captures the total economic value of the MPA (Pomeroy et al. 2006).

Thus a solution to attend this need has been monetization of the benefits or costs associated with the ES focusing on the consequences of the loss and the restoration cost of some core ecosystems in MPA recognizing what most people are willing to pay (WTP) or willing to accept (WTA) when some ES disappear (Schuhmann 2012). Methodologies that ask people to value ecosystem services are therefore useful and understand the complex linkages between biodiversity, ecosystem services, and value that are necessary (Bockstael et al. 2000).

Valuation of ecosystem services is a difficult task since interactions between ES and human well-being have to be clearly defined in order to become realistic (Turner et al. 2010). For many decades academics have been proposing, integrating, and proving some techniques such as cost based, revealed preference, and stated preference analysis, but scientific complexity, budget limitation, and the lack of a global understanding of interdisciplinary groups make the results unclear or uncertain; however, bundling and integrating synergies should allow a deeper understanding to solve it (Braat and De Groot 2012).

Some of the techniques, descriptions, and typical data that can be measured with the different uses of ES are listed in Table 19.1 which includes revealed preference and stated preference methods. The differences between these two categories of valuation methods are summarized below, but in short the main differences are: Revealed preference approaches depend on a connection between the nonmarket and market good of interest (Haines-Young and Potschin 2010). On the other hand, stated preference techniques evaluate hypothetical scenarios to seek a monetary value (Maynard et al. 2010).

Both revealed and stated preference methods can capture use values. It is important to consider that before any economic analysis of value can be achieved, the statement of the problem must induce a precise and detailed definition of the ES that is being valued (Hubacek and van der Bergh 2006). A measure of ES using the techniques and methodologies established must be effective for a relevant and quality policy (Balmford et al. 2008).

19.3 Methodology

19.3.1 Integrated Participatory Framework

The integrated participatory framework for valuing marine and coastal ecosystem services defined by Lopes and Videira (2013) was adapted to the area; definitions and classifications from MA (2005), TEEB (2010), and UK NEA (2011) were integrated to structure the methodology represented in Fig. 19.5 that is split into the following elements: (1) identification of the socio-ecological interactions of marine and coastal ecosystems through an analysis of use and nonuse values and the needs and motives of ecosystem change and identification of stakeholders, (2) conceptualization of the main marine and coastal ecosystems, and (3) identification of the value preferences from visitors about the MPA.

19.3.2 Travel Cost Method

The travel cost method (TCM) is applied to determine the social values from a specific area that has recreational interest provided by the ecosystems. TCM is a tool that allows determining the demand function of a place and consequently the surplus of

Table 19.1 Valuation techniques for ecosystem services

Techniques	Types	Description	Typical data	Use measured
Cost based	Replacement cost	Estimates the costs that would be incurred if ecosystem services or benefits had to be recreated through artificial means	Cost of damage or cost of infrastructure replacement	Use value
	Avoided cost			
	Mitigation cost			
	Restoration cost			
Reveled preferences	Market price	Estimates economic values for ecosystem products or services that are bought and sold in commercial markets	Market price of ecosystem goods or services. The costs involved to process and bring the product to market	Use value
	Production function	Estimates economic values for ecosystem products or services that contribute to the production of commercially marketed goods	Data on changes in the output of a product. Data on cause and effect relationship	Use value
	Travel cost	Estimates economic values associated with ecosystems or sites that are used for recreation. Assumes that the value of a site is reflected in how much people are willing to pay to travel to visit the site	Uses data on people's actual behavior in real markets that are related to the environmental good in question rather than their conjectured behavior in hypothetical markets	Nonuse value
	Hedonic pricing	Estimates economic value of the relationship between some forms of individual behavior and associated environmental attributes	Data is revealed through observations of the demand and is related to differences in property prices or wage rates that can be ascribed to the different ecosystem qualities	Nonuse value
Stated preferences	Contingent approach	Estimates and infers ecosystem values by asking people directly what is their willingness to pay (WTP) for them or their willingness to accept (WTA) compensation for their loss saved	Data arising from interview or questionnaires deployed on a targeted group of people, and control group of persons is the value that people place on an ecosystem good or service	Use value/ nonuse value
	Choice modeling	Presents a series of alternative resource or ecosystem use options, each defined by various attributes set at different levels (including price) and asks respondents to select which option (i.e., sets of attributes at different levels) they prefer	As the contingent valuation approach uses questionnaires, choice modeling adds different contrast and scenarios. An appropriate set of levels are required for the different parameters	
Benefit transfer	Benefit transfer	Involves transferring value estimates from existing economic valuation studies to the study site in question, making adjustments where appropriate	Literature data, previous valuation analysis, and different applied models	All

Based on TEEB (2009), Gomez-Baggethun et al. (2010)

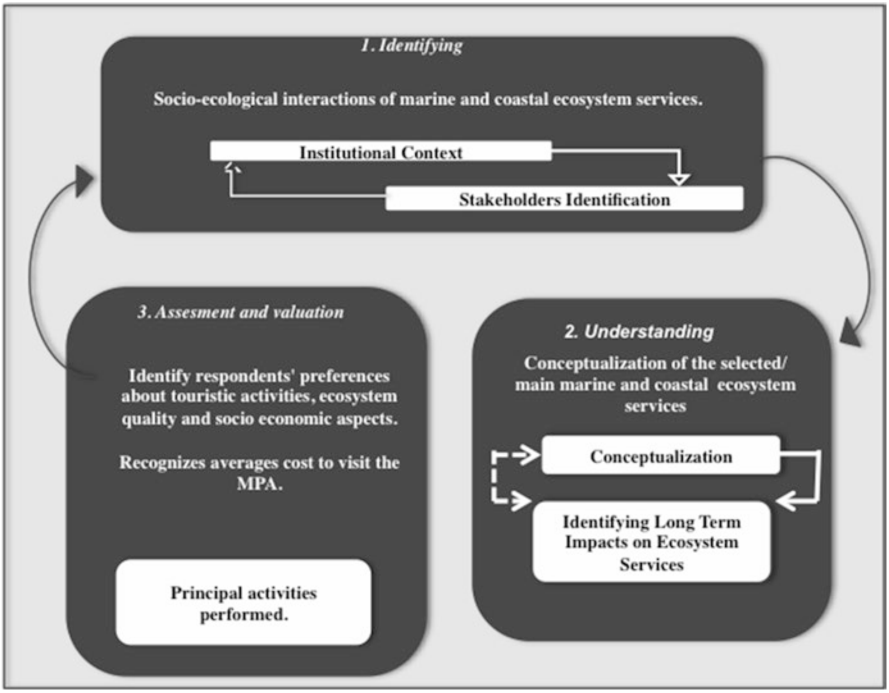


Fig. 19.5 The integrated participatory framework for valuing marine and coastal ecosystem services. (Source: Adapted from Lopes and Videira 2013)

the consumer. Therefore, many economists classify this method within the category of use of demand curves.

The travel cost method (TCM) is applied to determine the social values from a specific area that has recreational interest for the ecosystems and services that some areas provide, but also TCM can be applicable to other goods (Kaufman 2013). TCM is a tool that allows estimation of the demand function of said space and, consequently, the consumer surplus. Therefore, many economists classify this method within the category of use of demand curves (Samuelson 1947).

Hotelling (1947) proposed the TCM as a scheme to assign entrance fees to natural parks in the USA in order to fulfill the requirement of the National Park Services (NPS). Trice and Wood (1958) applied this methodology to estimate the recreational economic value of a river in the USA; nevertheless Clawson and Knetsch (1968) are the authors who mostly influenced the application of the TCM as a tool to value the economic benefits of natural resources after applying the mentioned method in the Yosemite National Park in California (1941).

The methodology pretends to demonstrate that even ES provided by the MPA related to the recreational experiences are not traded in the market, people can provide information about what they would be willing to pay in order to estimate an economic value (Walls et al. 2009). According to Boyd (2007), an individual places a particular value to each ES that translates into economic value through surveys, indicating either the willingness to pay (WTP) or the willingness to be compensated for the loss (WTA).

The individual travel cost method (ITCM) has been the most applied in the literature. The ITCM aims to determine the demand for recreational services from a place of each visitor using the function mentioned below specified by Layman et al. (1996):

$$V_{ij} = f\left(C_{ij}, Y_{ij}, D_{ij}, Q_{ij}, S_{ij}, e_{ij}\right)$$

where

V*ij*: number of visits of person *i* to site *j*
C*ij*: travel cost of individual *i* to visit site *j* (including the opportunity cost)
Y*i:* income of individual *i*
D*i*: a vector of sociodemographic characteristics of individual *i*
Q*j*: a vector of specific characteristics of the site *j*
S*ij*: the cost of the individual *i* to visit substitute sites
e*ij:* the stochastic term

Haab and McConnell (2002) mentioned that TCM is a model of demand for services for a recreational site. Both authors indicate that the principle of the method is related with the need (or decision) to travel to a site with natural resources that provide services to practice recreational activities and to enjoy their services, including environmental services. Someone who decides to visit the site will incur certain costs (Leimona 2011).

19.3.3 Sampling and Survey Administration

The sample was determined by random sampling, taking 20,000 total visitors to ESI in 2014 according to the information given by the director of ESI. Having an estimation error of 5% and given to *p* (the success likelihood) a value of 0.5, $q = 1\text{-}p$, and 95% of confidence. We obtain a total of 235 surveys to be conducted to ESI visitors during the months of November 2015 to March 2016. The survey was only for visitors 18 years old and over, and it was applied after the visitors returned from the MPA. The surveys were face to face. The survey had 18 questions divided into three sections: the first one focused on the sociodemographic characteristics (country of origin, age, gender, annual income); the second section focused on the characteristics of the trip, requiring information about means of transport (airplane, car, other) as well as inquiring the costs of rental vehicles, the cost of lodging, the cost of the food consumed during their stay in the city of La Paz, the days spent in the city of La Paz, and the number of times they have come to the ESI; and the third section focused on the activities performed in the ESI (scuba diving, snorkeling, whale watching, recreational fishing, and other recreational activities) as well as inquiring how much they paid to practice the aforementioned activities and about the ecosystem quality and MPA knowledge (Bobadilla-Jimenez et al. 2017). The questions that were considered to design the survey provided relevant information of the travel expenses incurred by the visitors, the touristic activities practiced, and their socio-economic characteristics. A database was created and coded, and the variables are described in Table 19.2.

Table 19.2 Description of the variables included in the survey

Classification	Variable	Description
Socioeconomic	Origin	Describes the origin of the respondents – 1, Mexican; 2, American; 3, Canadian; 4, European; 5, other
	Age	Indicates the age of the visitors; the study just considered individuals over 18 years
	Gender	Indicates 1, female, and 2, male
	Education	Indicate level of study – 1, primary; 2, secondary; 3, high school; 4, university; 5, master's degree or higher
	Annual income (US DLLS)	Annual income of visitors
About the visit	Visits since 2000	Dependent variable that is used in the study to determine the time period the visitor has visited the MPA
	Transportation	Describe the means of transport used to get to site – 1, airplane; 2, own car; 3, rental car; 4, other
	Cost of transportation	Request information regarding the payment made for the round plane ticket
	Cost of consumed food	Ask for information regarding the payment made for food during the stay in La Paz
	Cost of lodging	Ask for information regarding the payment made for lodging during the stay in La Paz
	Days of stay	Days spend in la Paz
	Travel cost	Total amount paid from its departure from destination
Reasons of the visit	Scuba diving	Recreational activity practiced in the ANP – 1, practice the activity, and 0, does not practice
	Snorkel	Recreational activity practiced in the ANP – 1, practice the activity, and 0, does not practice
	Whale watching	Recreational activity practiced in the ANP, 1: Practice the activity 0: Does not practice
	Recreational fishing	Recreational activity practiced in the ANP – 1, practice the activity, and 0, does not practice
	Others	The other activities allowed in the park
	Ecosystem quality	Indicates on a Likert scale how the visitor evaluates the ecosystem quality in the MPA – 1, poor; 2, bad; 3, regular; 4, good; 5, excellent
	MPA knowledge	Indicates if the visitor has knowledge of the place he is visiting – 1, knows it is an MPA, and 0, does not know it is an MPA
	Payment	Payment that the visitor makes to develop an activity

Source: own elaboration

19.4 Results

Socio-ecological interactions were analyzed and integrated in four dimensions (Fig. 19.6); the first are the beneficial ecosystem processes that directly underpin benefits to people (adapted from TEEB 2009). This analysis is focused on representing the diversity, interactions, products, and use (direct and indirect) that coastal and marine ecosystem provides and also analyzes which needs and motives are changing the ecosystems (in a positive and negative way) with specific stakeholders.

The first section is focused in the ecosystems processes that the analysis follows, the main benefits that ESI provides and are represented by: Production; related with the production of plant and animal biomass, the nutrient cycle, habitat provision, focusing on the formation of the physical properties for the habitats necessary to many marine species in ESI, the habitat also allows the diversification of species), and the genetic diversification, this **MPA** also promotes waste assimilation through the removal of contaminants and the erosion control. For tourism in ESI, all the combinations of ES allow the formation of pleasant scenery (principally seascapes that are attractive to tourists); modulation of regional/local climate is another benefit provided by ESI which includes the regulation of water quality and purification of contaminants of the water in an ecosystem (Gómez-Baggethun et al. 2010; Fletcher et al. 2011).

The second section is focused on the use and nonuse values, following the framework of the Millennium Ecosystem Assessment (MA 2005). Four categories of ecosystem services (provisioning, regulating, supporting, and cultural) were included

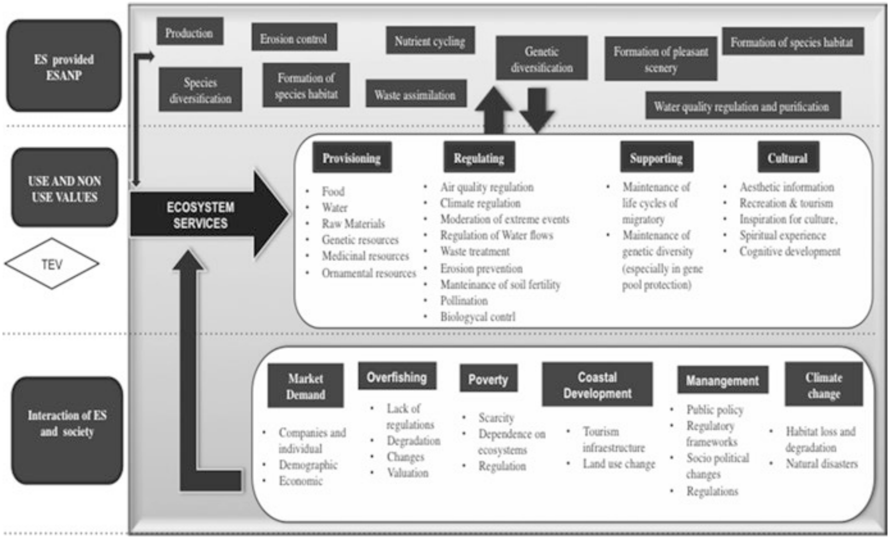


Fig. 19.6 Socio-ecological interactions of marine and coastal ecosystem services (own elaboration)

according to the classification of the MA (2005). The ecosystem services were included here in order to represent the complete framework. The third one is focusing on the interactions between ecosystem services, human well-being, and drivers of change that cause modifications in marine and coastal ecosystems; a total of six direct and indirect drivers of change were included in this dimension:

1. Market demand: an increment of businesses developing the economic activities related with marine and coastal ecosystem services and individuals trying to attain the economic development.
2. Overfishing: the lack of regulations have driven the degradation and changes in some marine and coastal ecosystems.
3. Poverty: dependence on degraded ecosystems is affecting coastal populations causing scarcity of many resources and reducing their incomes.
4. Coastal development: the government has focused on the development of tourism as the main activity in coastal areas, allowing tourism infrastructure access in sensible ecosystems.
5. Management: public policies and regulatory frameworks are increasing in coastal areas affecting both in positive and negative ways; sociopolitical demands and implementation are changing; but trade-off analysis, future development scenarios, and ES valuation still needed to provide well-defined alternatives including all the interactions.
6. Climate change: this affects vulnerable ecosystems, causing sea level rises and increased storm events.

19.4.1 Tourism Interactions of ES in ESI

Besides the interaction of socio-ecological functions and systems, it is important to represent the principal characteristics of the tourists who come to ESI to practice different activities; also recognizing the natural and economic resources provided by ES promotes the interactions that allow increasing of many (e.g., species, people, financial and economic resources) and decreasing of others (e.g., extinction, poverty, scarcity). Recognition and identification of the biodiversity have been helpful to value and demonstrate that management of this MPA should include well-defined connections in order to understand the way the cost of biodiversity can affect or benefit the whole system.

19.4.2 Sociodemographic Characteristics of Respondents

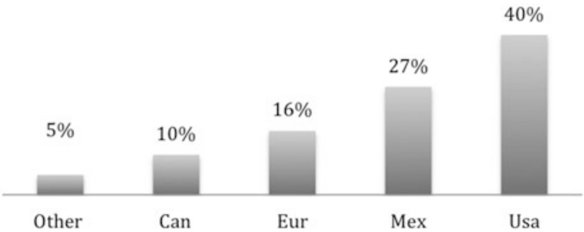
From the sample we could see that 73% are foreign visitors; disaggregating them by origin, there are 40% of this group from North America, 11% from Canada, and 16% from Europe. Twenty-seven percent is national tourism (includes visitors from other municipalities and other states), and the remaining percentage is from other countries without specifying (Fig. 19.7).

The sample shows an average age of 39 years. The genders of visitors are 44% men and 56% women. With a high level of education, 46% is located at the top level, and the average annual income is $13,061 DLLS. The means of transportation visitors used the most to arrive to the City of La Paz was airplane (73%) and by driving their own car (23%); the rest reported unspecified means of transportation. In terms of vehicle rental costs, $400 DLLS was the maximum; the average cost of accommodation was $114 DLLS and a maximum of $1100 DLLS; and the average for food consumption during their stay in La Paz was $52 DLLS, and the maximum was $450 DLLS. The average total cost of the trip is $627 DLLS, and the maximum is $2150 DLLS.

The average number of visits to ESI from visitors in the period from 2000 to the present was two visits; the number of visits being at least 1 and the maximum 12 times. The average stay in the City of La Paz is 1.5 days and the maximum is 20 days. Of the recreational activities carried out in the area, the following stand out: (1) scuba diving, (2) snorkeling, (3) watching of flora and fauna, and (4) sport fishing.

Figure 19.8 shows the activities that are carried out most frequently by visitors. Visitors declared that they have made an average payment of $100 DLLS for practicing some of the recreational activities during their visit to the ESI and a

Fig. 19.7 Origin of visitor (own elaboration)



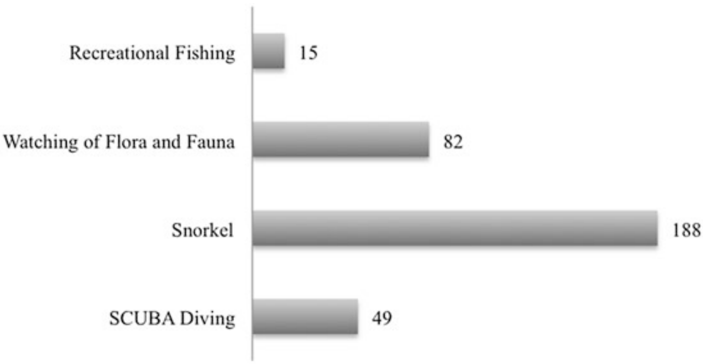


Fig. 19.8 Recreational activities performed in ESI (own elaboration)

maximum of $400 DLLS, highlighting that some of them perform more than one activity per visit.

Fifty percent of the visitors declared that the quality of the ecosystems in the ESI is excellent, 32% of the visitors considered their quality as good and 15% of the visitors considered it as regular, the rest of the visitors consider it as bad. Eighty-two percent of the visitors declared to know that the Park is an MPA.

19.4.3 Estimation of Willingness to Pay to Access ESI

Variables used in the estimated models for ESI are described in Table 19.3. Four models were estimated, one for scuba diving (Model A), another one for snorkeling (Model B), the third one for flora and fauna appreciation (Model C), and the final model for sport fishing (Model D). The dependent variable in the four models was

Table 19.3 Variables used in the estimated models for the ESI

Abbreviated variable	Meaning	Definition
V_2000	Number of visits since 2000	Visits made by the individual since 2000
C_VIA	Travel cost	Total amount paid from its departure from destination
C_HTL	Cost of lodging	Ask for information regarding the payment made for lodging during the stay in La Paz
C_ALI	Cost of consumed food	Ask for information regarding the payment made for food during the stay in La Paz
LHOT	Logarithm of lodging	Logarithm of the payment made for lodging during the stay in La Paz
DEST	Days spend in La Paz	Days spend in la Paz
TP_TRANS	Means of transportation	Describe the means of transport used to get to site 1, airplane; 2, own car; 3, rental car; 4, other
PROCE	Origin	Describes the origin of the respondents 1, Mexican; 2, American; 3, Canadian; 4, European; 5, other
CA_ECO	Ecosystem quality	Indicates on a Likert scale how the visitor evaluates the ecosystems quality in the MPA: 1. Poor, 2. Bad, 3. Regular, 4. Good, 5. Excellent
EDAD	Age	Age of the respondent was 18–77 years
GEN	Gender	Indicate 1, female, and 2, male
N_EDUC	Education	Indicate level of study 1, primary; 2, secondary; 3, high school; 4, university; 5, master's degree or higher
IN_USD	Annual income (US DLLS)	Annual income of visitors
LY1	Logarithm of income	Logarithm of the annual income of the visitor

own elaboration

the number of visits to ESI since year 2000 (V_2000). All variables included in all models were statistically significant at 10%, 5%, and 1%.

For the ESI four models were estimated (Table 19.4), a model for the activity of autonomous diving (A), another for the free diving activity (B), one for the activity of observation of flora and fauna (C), and one for the activity recreational sport fishing (D), in which the dependent variable was the number of visits that the individual has made since 2000 (V_2000). For all models, the variables included are significant at 10%, 5%, and 1%.

For **Model A** (scuba diving), the coefficient for the travel cost (C_VIA) indicates that if travel cost increases, the probability of visiting ESI will decrease. The PROCE variable shows that if the origins of the visitor increase, visitation also increases. The coefficient for IN_USD indicates that if visitor income increases, the number of visits to ESI will also do the same. There is no elasticity.

In **Model B** (snorkeling), the coefficient for the travel cost is negative, corresponding with economic theory, indicating that higher cost implies fewer visits to ESI. If visitor income (IN_USD) increases, also does the visitation likelihood to ESI. The coefficient for DEST indicates that shorter stay (in days) lowers the visitation probability to visit ESI. If the visitor appreciates an improvement on the ecosystem quality (CA_ECO), then the probability to visit ESI will increase.

For flora and fauna observation model (**Model C**), if travel cost increases, the number of visits to ESI will decrease. If visitors practice flora and fauna observation activities, then the number of visitor from the same origin place will increase. The day of stay affects in a negative way the visitation frequency. Educational level (N_EDUC) affects negatively the number of visits to ESI; also age affects negatively because the more aged the visitors are, the less visits ESI will receive.

The travel cost coefficient in the recreational fishing model (**Model D**) is negative, indicating that if travel cost increases, visits to ESI will decrease. The transportation (TP_TRANS) is relevant in the model, indicating that if the visitor classify and choose the different means of transportation to access ESI, then the number of visits will decrease. If visitors perceive a reduction in ecosystem quality (CA_ECO) of ESI, then visits will also be impacted in a negative way. The natural logarithm of income is taken as the demand-income elasticity, indicating that if income increases 1%, then visit will also increase about 0.58%.

As coefficients only show how the visitor moves, marginal effect estimation for elasticity was conducted for the four models (Table 19.5). For **Model A**, if travel cost increase 1%, then visits will decrease 0.08%; if the individual income increase 1%, then visits will do so in about 0.08%. PROCE has a positive influence on visits. Elasticity for **Model B** indicates that if travel cost increase in 1%, visits will decrease about 0.03%; an increase of 1% on income will increase visits in 0.48%; PROCE, DEST, and TP_TRANS have positive influence on visits to ESI. In **Model C** the travel cost elasticity indicates that if this variable increase 1%, then visits decrease in 0.12%; if IN_USD raise 1%, then visits will decrease 0.05%; N_EDUC has a positive influence on visits; and DEST, CA_ECO, GEN, and AGE have a negative influence on the dependent variable. Finally, for **Model D** when travel cost increase 1%, the visits to ESI diminish 1.87%; TP_TRANS has a positive impact on visits, and DEST and CA_ECO have a negative influence on the number of visits to ESI.

Table 19.4 Models for recreational activities in ESI

	Model A		Model B		Model C		Model D	
Dependent variable number of visits	SCUBA diving		Snorkel		Flora and fauna observation		Recreational fishing	
Variable	Coefficient	P>z	Coefficient	P>z	Coefficient	P>z	Coefficient	P>z
C_VIA	−0.0001108	0.0000	–	–	–	–	−0.0018474	0.0000
C_HOT	–	–	–	–	−0.0009457	0.0000	–	–
C_ALI	–	–	−0.0002983	0.0000	–	–	–	–
PROCE	0.017604	0.0010	0.3801252	0.0000	0.8987167	0.0000	–	–
IN_USD	5.24E-06	0.0000	4.34E-06	0.0010	−1.11E-06	0.0000	–	–
DEST	–	–	1.054372	0.0000	−0.0499834	0.0000	−0.0180956	0.0720
TP_TRANS	–	–	–	–	–	–	0.815162	0.0000
CA_ECO	–	–	0.0997724	0.0000	−0.789271	0.0000	−0.1397109	0.0900
LY1	–	–	–	–	–	–	0.5857203	0.0000
GEN	–	–	–	–	−0.2836383	0.0000	–	–
N_EDUC	–	–	–	–	0.5225256	0.0000	–	–
EDAD	–	–	–	–	−0.0140196	0.0000	–	–
_cons	−0.4650294	0.0000	−0.5271775	0.0000	1.463503	219.7700	−3.789128	0.0000
Log pseudo likelihood	−37.926738		−29.555653		−1342758.9		−307.27299	
Pearson R2	0.9952		0.9879		0.4089		0.9707	
Wald chi2	81,911.27	0.0000	7448.12	0.0000	1,363,082.7	0.0000	111.08	0.0000
AIC	85.85348		71.11131		2,685,536		626.546	
BIC	93.90807		79.10453		2,685,641		647.817	
WTP	25		66		17		12	

own elaboration

Table 19.5 Marginal effects to recreational activities in ESI

	Model A	Model B	Model C	Model D
Dependent variable Number of visits	Scuba diving	Snorkeling	Flora and fauna observation	Recreational fishing
Variable	Elasticity	Elasticity	Elasticity	Elasticity
C_VIA	−0.0898***	−0.0304***	−0.1211***	−1.8762***
PROCE	0.0309***	0.0199***	1.7581***	
IN_USD	0.0797***	0.4887***	−0.0515***	
DEST		0.1353***	−0.0269***	−0.0843*
TP_TRANS				0.7133***
CA_ECO		0.0378***	−3.2763***	−0.4508***
LY1				5.9201***
GEN			−0.3358***	
N_EDUC			1.7951***	
EDAD			−0.5949***	

own elaboration
*** Statistically significant at 0.01
* Statistically significant at 0.10

Travel cost elasticity indicates that despite if access fees to ESI could be modified, visit demand will not have a significant reduction; for each activity this reduction will be around one visit per year. Demand-income elasticity in Models A, B, and C (scuba diving, snorkeling, and flora and fauna appreciation) indicates that visits to ESI are normal (basic) goods, and for Model D (recreational fishing), visits to ESI are luxury goods.

19.5 Conclusions

Emphasis on the importance of biodiversity in ESI is not only based on the imposition of a current trend to achieve sustainability or the continued imposition of environmental groups; ecosystems are linked to social systems since humans depend on the ecosystem functions to fulfill their needs and aspirations; these interactions seem not to require many efforts; determining the importance of natural capital is crucial to also understand how the direct and indirect drivers of change or the causalities of processes eventually affect ecosystem services and human well-being. Some of the benefits of marine and coastal ecosystems were discussed on this paper, and a continuous gap still remains on the importance of interactions between ecology and social sciences, to understand the vital interactions (benefits, visible, tangible, invisible, or designed) between ecosystems and social systems that finally determine the overall well-being of humanity.

Marine and coastal ecosystems of the ESI are important for the interactions with people and the environment, connect all the bundles and translated to policy arena is what make a research successful, for this analysis a section of ES of ecosystems were presented, it is necessary a broad recognition integrating the value of ecosystem into a socio-ecological analysis.

Even if the ESI has a management plan which has been followed, not all the regulations have succeeded; many failures at the moment of regulating the number of visitors, the fishing permits, and the protection of some species have been presented; even if the ESI has been with this management a while ago, a major involvement of the tourist community and locals is needed in order to keep and maintain the mentioned ES.

Definitely classifications for ecosystem services have evolved and have been helpful to developed regional evaluations worldwide. For marine and coastal ecosystems, classifications are still evolving, and many authors are proposing different ways of valuation for specific ecosystems. For this research MA, TEEB, and UK NEA frameworks were used as a guide to construct and develop a socio-ecological framework for Baja California Sur, a consideration that more ecosystem services exist and interactions are well-thought-out (e.g., offshore ecosystems), and a suggestion is continuing with the implementation of different methods, and research is recommended.

Establishment of MPA does not guarantee the achievement of these goals. To be effective and to reach their objectives, management plans for MPA must define specific and measurable objectives in terms of the products and results they expect to obtain. MPA cannot be managed in the same way since each of them has unique biological, economic, and cultural characteristics.

In Mexico regulations are increasing and improving its regulatory policy in order to implement initiatives to adapt and define policies to preserve and conserve ecosystems through different instruments, the most important of which is the General Law of Ecological Balance and Environmental Protection (LEEGEPA), which is focused on the preservation and restoration of ecological balance, as well as environmental protection; also institutions such as Secretary Of Environment and Natural Resources (SEMARNAT); National Commission of Aquaculture and Fishing (CONAPESCA); National Commission on Biodiversity (CONABIO); Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA); National Commission of Natural Protected Areas (CONANP), and the Mexican Secretary of Tourism (SECTUR) are working hard to preserve marine and coastal ecosystems in Mexico and in the State of Baja California Sur. Nevertheless slow process and definition of policies have been a big barrier to implement and define actual recommendations from academics and scientifics; also the lack of integration of some institutions and governmental sector avoids streamlines to follow the conservation, regulation, and economic process.

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Chapter 20
Biodiversity Conservation in the Pantanos de Centla Biosphere Reserve: Ecological and Socioeconomic Threats

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Abstract Natural resources and their biological richness are threatened by the chain of processes and activities derived from population growth and transformation activities. NPAs are not free of these changes. The Pantanos de Centla Biosphere Reserve (RBPC, by its Spanish acronym), with its surface area and ecological characteristics, is one of the most important wetland complexes of Mesoamerica. However, several socio-productive activities that take place in it affect the ecosystem's integrity. A literature review was carried out to establish the degree of research on the RBPC. Following a conceptual model of threats in natural protected areas, pressures were described considering natural processes, inadequate management of threats and secondary effects. Nine categories were established: (1) recreational use and management, (2) management of crops and grazing, (3) management of fires, (4) introduction of exotic species, (5) diversion and reservoirs (waterworks), (6) emission of pollutants, (7) climate change, (8) management of adjacent lands and (9) other threats related to public and social policies.

Keywords Fragmentation · Pollution · Natural area · Southeastern · Mexico

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20.1 Introduction

On a global scale, natural resources and their biological richness are going through important processes of transformation and deterioration due mainly to population growth and the unsustainable development of economic activities. This has led to a deterioration of ecosystems, including those that form and part of natural protected areas (NPAs) (Barba-Macías et al. 2014a; MacDonald et al. 1989; Tu 2009). Mexico has a great variety of terrestrial, freshwater and marine habitats, geomorphological features and climate and plant and animal zones. It provides crucial elements for the conservation and management of the regional and global biodiversity due to its geographical location between the temperate and tropical regions (Valdez et al. 2006).

In Mexico there are 182 federal NPAs administered by the National Commission of Natural Protected Areas (CONANP, by its Spanish acronym) (CONANP 2014). Pantanos de Centla Biosphere Reserve (RBPC, by its Spanish acronym), located in the Mexican southeast, is on the coastal plain of the Gulf of Mexico, in the state of Tabasco (Fig. 20.1). Its hydrological and geological characteristics render it as one of the most important wetlands of Mesoamerica and recognized internationally as a NAWCA, a RAMSAR and a MAB site and as an area of interest for the conservation of birds (IREBIT 1994). Because of its 110 freshwater bodies (13,665 ha) in the RBPC, the marsh and swamp wetlands cover the greatest surface area (44%) (Barba-Macias et al. 2006).

20.1.1 Socioeconomic Context

The RBPC has been changed in diverse ways to give way to different productive activities that have given profits to some sectors and caused a loss of opportunities and natural resources to others (Guerra-Martínez and Ochoa Gaona 2008). Most of the resident population includes fishermen, farmers and ranchers (cattle raising) descended from Chontal ethnic group that have a deep and ancestral knowledge of their lands and base their economy on the extraction of natural resources (Romero-Gil et al. 2000). Land use includes 53.1% of common lands ("ejidos"), where the difficult access and constant floods have limited human activities. However, agriculture, ranching and urban and industrial areas have increased, generating a constant pressure on the reserve (IREBIT 1994). The main activities are agriculture, urban, industrial and others. This last one includes different activities related to the high-impacting oil industry, with over 55 oil and gas fields in the area (Palma et al. 1985; PEMEX, EXPLORACION 1997).

The purpose of this chapter was to gather and systematize the main ecological and socioeconomic threats that affect the conformation and management of the RBPC. The analysis started with a review of literature on environmental, ecological and socioeconomic subjects published for this reserve. In order to systematize the

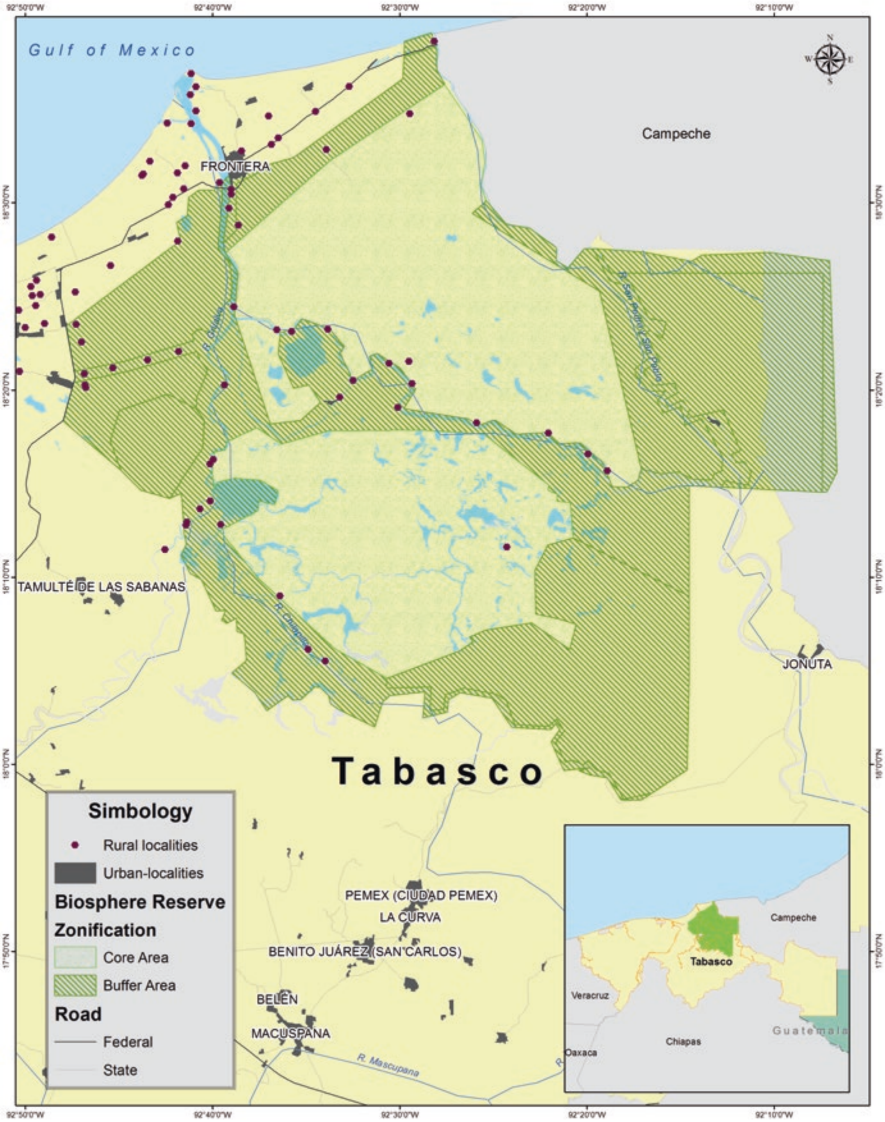

Fig. 20.1 Location and zonation of RBPC (Map provided by Díaz-Pereira)

information, a modified Machlis and Tichntll (1985) conceptual model was used to group threats that include natural processes, inadequate management of threats (e.g. inadequate financing and personnel) and secondary effects (e.g. erosion caused by cattle hoofs). Most of the impacts that affect the ecosystem are grouped into nine categories: (1) recreational use and management, (2) management of crops and grazing, (3) management of fires, (4) introduction of exotic species, (5) diversion

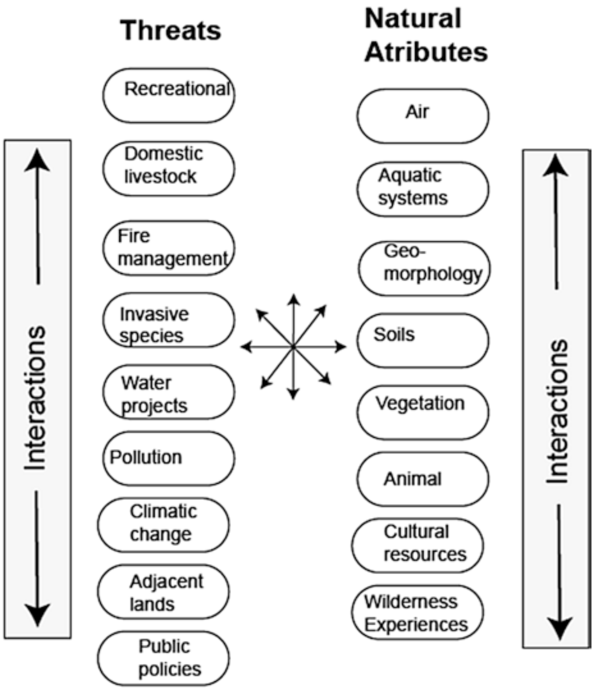

Fig. 20.2 Relationship between threats and attributes of the RBPC (Modified from Machlis and Tichntll 1985)

and reservoirs (waterworks), (6) emission of pollutants, (7) climate change, (8) management of adjacent lands and (9) other threats related to public and social policies (Fig. 20.2).

20.2 Description of Threats

20.2.1 Recreational Use and Management

Tourism activity in the RBPC is still small-scale, despite official efforts that have been carried out with the expectation of exploiting the natural vocation of the landscape, such as its attractiveness, and promoting a diversification of the local economic activities. These mainly include the observation of landscapes and of flora and fauna in their natural habitats, as well as guided visits and tours. Twelve areas have ecological tourism potential: Laguna El Coco, Arroyo Polo, Tres Brazos, Sistema Lagunar San Pedrito, Arroyo San Pedrito, Canal Nueva Esperanza, Sistema Lagunar Salsipuedes, El Faisán, La Pera, Tembladeras, Laguna el Cometa and Sistema Lagunar el Viento. In 2000, the state government designed a tourism route named “Pantanos” (swamps, marshes, wetlands) in which the natural attributes of the NPA are promoted, within the tourism axis of the state “Villahermosa-Frontera”, a nature tourism project (Frontera-Jonuta axis) and a gastronomic tour including rustic restaurants (Gobierno de Tabasco 2014).

Ecotourism in the RBPC was seen as a mechanism for the indirect and passive use of the natural resources of the area, working as a short-term activity to obtain income to support the management of the area and raise the quality of life of the local inhabitants. However, infrastructure and support services such as lodging and restaurants were limited (SEMARNAP 2000). In general, the natural and cultural attractions in Tabasco do not have a strong presence in the tourism market. According to Guzmán-Sala and Mayo (2016), the lack of infrastructure, trained personnel and guided tours, the low-quality attention and recreation services and the scarce promotion of the attractions make it difficult to catch the attention of potential tourists or to adequately satisfy visitors.

The national strategy for a sustainable development and tourism and recreation, for the NPAs in Mexico, analyses the tourism phenomenon of each area in order to define particular action priorities. For this, each NPA head office determines the level of development for tourism for the protected area (incipient, planned, predator and managed) and the tourism management that the CONANP carries out (exploratory, preparatory, reactive and proactive). For the RBPC, tourism has been classified as "managed/proactive". However, currently the RBPC does not appear on the list of NPAs with tourism vocation (CONANP 2016).

Some efforts have supported the conservation of biological diversity by means of a reward to resident working groups that carry out actions for sustainable development through the Conservation Program for Sustainable Development (PROCODES). In the RBPC (years 2008–2016), an investment of US$119,570.00 was made to support ecotourism activities covering two items: projects and courses. The projects focused on buying outboard motors for boat trips and on maintenance of facilities (restaurants, kitchens and lodging), with 19 projects in 7 localities and an investment of US$103,385.00. The courses were based on the production of arts and crafts with natural fibres, the interchange of experiences among tourism operators and the strengthening of the organization, management and administration, with 15 courses in 9 localities and an investment of US$22,470.00 (Morales 2018). Notwithstanding these aids, tourism activities are in trouble as there is no coordination among the providers of ecotourism services, incentives are given by different institutions (CDI, CONAFOR, CONANP, etc.), the areas used are overlapped and there is competition for tourists (Barba-Macías et al. 2014a).

Other activities that take place in the RBPC include those related to the promotion of education and training in environmental matters. The interpretation centre "Uyotot Já", known also as the "Water House", was created with social and federal participation and other donors like PEMEX. Its infrastructure is operated mainly by the reserve direction and includes 5 stilt houses, 1 interpretive trail and a 20-m-high anti-fire vigilance tower that provide a panoramic view to visitors at the junction of the Grijalva, Usumacinta and San Pedro rivers (Tres Brazos). This increased visits from 1000 to 12,000 per year (ENDESU 2015; Gobierno de Tabasco 2014) from the year 2001 to 2015. For the years 2013–2018, a touristic route named "Agua y Chocolate" is proposed to be created and joins other efforts such as the placing of Centla on the Olmec-Maya route (Gobierno de Tabasco 2014).

Fig. 20.3 Maize crop and cattle, as socio-economical activities in RBPC

20.2.2 Management of Crops and Grazing

The inhabitants of the RBPC, named fishermen-farmers, traditionally combine work in orchards, planting for personal food, ranching, fishing and labour work. After fishing, ranching and agriculture are two of the predominant economic activities in the RBPC (Díaz-Perera et al. 2015). Although the activity is not intensive due to the low number of producers, the impacts on the landscape and biodiversity are noticeable.

As a result of multiple government plans or credit systems, ranching is one of the activities that receive most stimuli, generating a rush to reclaim land from wetlands. It is common that communities of rooted emergent hydrophytes are altered to build canals and embankments with a view to drain areas that flood so they can be used for ranching (Barba-Macías et al. 2014a). In fact, from 1990 to 2000, the dynamics of the change in the use of the soil in the core zones and the buffer zone were similar. The medium deciduous tropical forest ("pukteal", oxhorn bucida, *Bucida buceras*) and the low-flooded tropical forest ("tinto", bloodwood tree, *Haematoxylum campechianum*) presented negative change rates in all the management zones, while there was an increase in pastureland in all areas (Guerra-Martínez and Ochoa Gaona 2008).

Extensive ranching is the activity that developed most, covering 14% of the surface area in the RBPC. However, productivity is very low and receives a minimum economic investment, not considering the time and effort required for production per surface area. The most common cattle breeds are the commercial Zebu, the Swiss and their cross-breeds. Feeding does not include any type of chemical, grain or agricultural residue feeding supplements. In general, ranching takes place in low lands that can flood during most of the year, for which reason this activity is seasonal. During the rains, cattle owners rent higher areas where their cattle can survive the floods (SEMARNAP 2000) (Fig. 20.3).

Agriculture covers 1.2% of the total surface area and is located on alluvial plains and littoral areas (SEMARNAP 2000). Most of the marshy ground tends to flood every year, leaving agriculture only on higher land that is cleared of natural vegetation (frequently flooded tropical forest) by the slash and burn system. Agriculture is basically of the traditional type, destined to satisfy the feeding needs of the farming family. It is characterized by the null or scant use of supplies (fertilizers) and agricultural machinery, basically based on the family workforce to produce with a minimum economic investment. By its nature, agriculture may be classified as:

(a) *Perennial* crops represented by coconut, lemon, orange, mango and chicozapote (sapodilla)
(b) *Semi-perennial* crops combined with small orchards of perennial crops characterized by banana
(c) *Annual* crops of maize, beans, pumpkin, yuca (cassava) and habanero pepper (Fig. 20.3)

Both agriculture and ranching are subsistence activities (with surface areas smaller than 10 ha and herds of no more than 15 heads) carried out by people of scant resources, whereas commercial activities (with surface areas of 100 ha or more, sowing machinery and herds of up to 700 heads) are carried out by people with a high income (Díaz-Perera et al. 2015). These activities are considered incompatible in the reserve, but they receive important support from the state government which has even favoured the introduction of exotic crops such as the African palm and pastureland (Barba-Macías et al. 2014a).

20.2.3 Management of Fires

The RBPC is periodically subjected to fires caused by the inadequate use of fire mainly for the capture of wild fauna, for widening fishing areas and for clearing the access to turtle and crocodile burrows and caves to ease their capture. Fishermen also use fire in order to be able to use their nets in areas with southern cattail (*Typha domingensis*) during the flood seasons and for their agricultural activities to improve grass and to increase the frequency of maize crop planting to the south of the area where many producers burn illegally (Fig. 20.4).

The most important factors in fires are the climate (dry season, April and May), the plant fuel which is a very fine material and the indifference towards this type of events on the part of the inhabitants of the reserve, as well as the existence of a black market for turtle and crocodile skins during the Holy Week season of vigil when the illegal consumption of turtles increases following a lack of knowledge or of surveillance on the part of the municipal or common land authorities, among others, apart from intercommunity strife in border areas between community territories that may be under litigation, in the best of cases, or invaded (López-Portillo 2005).

The fires that occur in the reserve are either surface or underground fires. The first occurs mainly in associations of hydrophyte vegetation dominated by Jamaica swamp sawgrass (*Cladium jamaicense*) and southern cattail (*Typha domingensis*),

Fig. 20.4 Burned vegetation and fire in wetland area for extraction native fauna and change of use of soil

with propagation speeds of up to 250 ha per day and durations of 1–5 days. Underground fires are generated by surface fires when these reach forested areas (mangroves; medium deciduous tropical forests of oxhorn bucida, *Bucida buceras* (pukteal); low-flooded tropical forests of bloodwood tree, *Haematoxylum campechianum* (tinto); *Thalia geniculata*, alligator-flag shrubland (popal); etc.) where the dense accumulation of dry organic matter on the soil slowly burns without the presence of flames and only white smoke is to be seen. This type of fire is difficult to detect, particularly during long dry periods, as the effect known as "mist" which is produced by the great number of fires. The propagation speed of this type of fire is slower (10 ha per day), and its duration is longer, reaching 2–3 months (López-Portillo 2005).

The number of fires is related to the use of fire in agricultural activities, apart from cultural causes like using fire to scatter species (turtles and crocodiles) (Zenteno 2011). Between 1999 and 2003, 115 fires affected an area of 4664.95 ha. The most severe fires considering the affected area were those of 1999 (1474.2 ha) and those of 2001 (1253 ha). Regarding the number of fires, the year 2003 stands out with 38 events and 1144 ha affected. Fires in the RBPC occur every year and affect extensive areas of different types of vegetation. In an analysis of the anthropological alteration indices, the Chemical Index of Alteration (CIA) showed that 89.19% of the area presents some category of threat by fire. The highest categories were those of the Usumacinta River and the lowest were those of the Tabasquillo followed by the Grijalva. The medium value in the sampled points was 0.28, with values ranging from 0.17 to 0.51, though not statistically ($p = 0.096$) (Zenteno 2011).

20.2.4 Introduction of and Invasion by Invasive Exotic Species

Among the main threats to ecosystems is the introduction of invasive exotic species (IES), either intentionally or accidentally. This causes alterations in the ecological equilibrium with changes in the composition of species and in the trophic structure of the communities, the displacement or extinction of native flora and fauna species, changes and deterioration of habitats and changes in genetic diversity and the spread of diseases (Goldburg and Triplett 1997; Carlton 2001; D'Antonio and Kark 2002; Aguilar 2005; March and Martínez 2008), all of which have an effect on public health and the economy (Pimentel 2011; Pimentel et al. 2005).

In natural reserves, Macdonald et al. (1989) divided the impacts into (a) those on ecosystem function and (b) those on ecosystem structure, including changes in geomorphological processes, biogeochemical cycles, hydrological cycles, etc. This last is the most damaging type of impact (Tu 2009).

IES in Mexico may be found in all taxonomic groups and all ecosystems. The speed of invasion may be favoured by human activities in general, among which transportation of people and goods, commerce and the intensification of productive systems are to be noted (Badii and Landeros 2007). The main means of introduction are transportation in ballast water, aquaculture, boat fouling and aquarism (Okolodkov et al. 2007), together with an increase in the probability of introduction, colonization, establishment and dispersion of these species due to climate change (Hellmann et al. 2008).

This is one of the most critical threats that native species, aquatic habitats and biodiversity in general face (Hopkins 2001), with alarming data such as the extinction of 50% of freshwater fish species on a worldwide scale (Baillie et al. 2004), and where productive activities such as aquaculture and sport fisheries include exotic species of fish, crustaceans and molluscs (Welcomme 1992; Dextrase and Coscarelli 2000). However, it provides considerable social and economic profits, particularly in developing countries (Mendoza et al. 2011).

There is little information on the distribution and size of the IES populations in the NPAs of Mexico. It is known that at least 23 species reported in the list of the 100 most damaging invasive species of the world are in NPAs and 13 species are aquatic or are associated with aquatic environments. Aguirre Muñoz et al. (2009) reported at least 36 species in NPAs in different aquatic environments and of a variety of taxonomic groups (UNEP 2001). Southeastern Mexico harbours an important network of riverine ecosystems and wetlands, among which those of the Papaloapan and Grijalva-Usumacinta River basins are outstanding (Barba-Macías et al. 2006). The RBPC lies in this last one. The presence of 3 invasive species of molluscs, *Tarebia granifera*, *Melanoides tuberculata* and *Corbicula fluminea* (Barba-Macías et al. 2014b; Trinidad-Ocaña et al. 2016; Barba-Macías and Trinidad-Ocaña 2017), 3 of crustaceans, 11 of fish (Amador-del Ángel and Wakida-Kusunoki 2014), 5 of reptiles, 4 of birds and 12 of mammals has been documented, apart from 90-introduced invasive plant species, mainly grasses, legumes and inflorescences (UNIBIO 2013 www.unibio.unam.mx).

One of the best studied populations of IES in the RBPC is that of the devil fish (*Pterygoplichthys* spp), with information on sites of invasion, population dynamics (abundance, size and reproductive capacity) and impact on fishing activities (damage to fishing nets and equipment and a decrease in capture of commercial species) (Barba-Macías et al. 2014b, 2015). Similar are the recording and abundance of the molluscs *Tarebia granifera*, *Melanoides tuberculata* and *Corbicula fluminea* on the spatial and temporal scales (Barba-Macías et al. 2014b; Trinidad-Ocaña et al. 2016; Barba-Macías and Trinidad-Ocaña 2017).

Species of invasive fish were introduced for aquaculture and "repopulation" purposes in order to develop aquacultural fisheries (four species) promoted by government programmes, three species for decorations, another three were introduced accidentally, one species was introduced as biological control, and two for unknown reasons (Amador-del Ángel and Wakida-Kusunoki 2014). In several cases, introduction took place by multiple routes, as has been recognized worldwide by Welcomme (1988).

20.2.5 Diversion and Reservoirs (Waterworks)

Changes in the hydrologic system of Tabasco began in the year 1951, when the federal government set up the Comisión del Grijalva in order to boost an integral development of this river's basin, with the aim to control floods, drain areas with a potential for agriculture and build and maintain roads to boost irrigation projects. Since 1955, the course of the rivers Grijalva, Samaria and Zanapa was changed to protect the coastal plain from floods. The changing course of the river Grijalva was controlled through the building of the Nezahualcóyotl dam in 1959, which in turn strongly modified the coastal ecosystems of Tabasco and led to a relocation of part of the Tabascan population to 220 villages and 4184 homesteads (Alcalá-Moya 1986). The Malpaso dam was built between 1959 and 1964 in the state of Chiapas. This prevented 350,000 ha in the Chontalpa region from floods (Leyva-Peña 1970). During the 1970s, the region occupies now by the RBPC which was already modified by oil exploration works transforming the landscape through the building of a wide channel net for water transportation of perforation machinery and oil wells (now blocked). This helped to peasant to colonize the territory few decades later (Uribe 2016) (Figs. 20.5 and 20.6).

After the great flood of the year 2007 in Tabasco, the Integral Hydric Program of Tabasco (IHPT) carried out an integral action plan by which excess water from the La Sierra River would drain to the coastal plain through the lagoon systems adjacent

Fig. 20.5 Transform the landscape, use of machinery

Fig. 20.6 Tourism boats as activity in RBPC

to Villahermosa and those of the RBPC. This constituted an important series of changes in the hydrologic regime and water composition during the rainy seasons of every year (CONAGUA 2012).

The Usumacinta River carries the most important flow of all Mesoamerica, unchanged by human infrastructure except for a reservoir built by Guatemala on the Chico River. The flow has been estimated at around 1700 m^3 per second, which could generate up to 1850 MW of electric energy (Bennassi 1972). During the decade of the 1970s, the river was evaluated to determine its hydroelectric potential, and 38 points were selected to build dikes (Toledo 1982). By 2002, a project of five reservoirs that would provide an installed capacity of 1110 MW and an average annual energy generation of 7168 GWh (2% of the installed capacity of the country) was considered. This work would affect 48 human establishments susceptible to flooding, with more than 27,000 people in the Mexican section (CONAGUA 2012). The affected region would include the area of influence of the reserves Biosfera de Montes Azules and Lacantún; the APFF (Flora and Fauna Protected Area) Chan-Kin, Naha and Metzabok; and the communal reserves La Cojolita, El Cayo, El Chile, La Mar, Chicozapote and Tornillo, among others. In addition, this damming would cause a decrease in the water that flows through the RBPC and to the coastal zone, together with important consequences in the composition, conformation and functioning of the wetlands.

Completed recently were studies on the environmental, social and economic costs that building reservoirs on the Usumacinta River would carry (Delgado 2005; Amezcua et al. 2007). In addition, social resistance against the development of these reservoirs has been reported, as they would affect the lands of a very important number of inhabitants, mainly native peoples (Castro Soto 2002, 2007). From an environmental perspective, hydroelectric plants along the Usumacinta River would affect the connectivity of the hydrologic systems of the basin, affecting both the functioning of the aquatic ecosystems and a number of greatly important species, several of which are already threatened or in danger of extinction and require this connectivity to maintain the health of their populations. At-risk species would be the manatee *Trichechus manatus*, the crocodiles *Crocodylus acutus* and *C. moreletii*, the white turtle *Dermatemys mawii* (Ippi and Flores 2001; Rodas et al. 2008) and other species of fish (bass, *Centropomus parallelus*; shad, *Megalops atlanticus*) and macroinvertebrates (painted river prawn: *Macrobrachium carcinus*) that carry out great migrations related to their life cycles throughout the basin.

20.2.6 Emission of Pollutants

Diverse activities related to the oil industry take place in the RBPC, among which are the laying of pipelines, the extraction of gas, the transportation and the building of canals. The plant communities along the right of way are characterized mainly by mangroves, wetlands, alligator-flag/southern cattail shrubs, high deciduous tropical forests and cultivated pastureland. Since all these are located in basins that receive runoff, they can be polluted by urban waste and oil spills (Palma and Cisneros 1996). Pollution by oil products may generate tension or even kill plants, although some species are continually regenerated by meristematic tissue (Freedman 1989).

Activities that take place around pipelines may cause a disturbance or loss of vegetation during right of way clearing for construction and maintenance purposes. Loss of vegetation has increased in recent years following the expansion of agricultural activities and human settlements. There is a great need to increase awareness among industry, government and the public on the dramatic decrease of the natural vegetation, as well as of wild fauna, and on the fact that the accumulated impacts of all developments, including that of the oil industry, may be important on the long run. Loss or alteration of native vegetation that occur during activities and around pipelines is unavoidable. However, mitigation measures may be established to reduce the area of this disturbance. Heavy vehicle traffic in the working area of the right of way may affect the layer of grass and cause the potential loss of the vegetation cover. In areas where native vegetation may be damaged along the right of way, the circulation of conventional vehicles should be restricted and inspection personnel should use low-pressure vehicles where necessary (Palma and Cisneros 1996).

In addition, and derived from activities up-river that affect the RBPC and the coast, runoff is generated by people and by agrochemical products used widely throughout the low basin of the Grijalva-Usumacinta, with runoff collecting in the polygonal area of the RBPC. According to 2008 survey, 30 communities established in the reserve use agrochemicals infrequently, although accumulation in the soil and water may generate an indirect effect due to the high dangerousness (organochlorines DTT and Lindano, bipyridil, paraquat) for wild fauna such as the wetland crocodile (Córdova-Carrillo et al. 2010). Their main use is as herbicides and for fumigation. Bioaccumulation of some of the most persistent agrochemicals may place at risk the habitat of Morelet's crocodile and other wild fauna in the reserve if agricultural activity continues to increase in the following years and the use of agrochemicals is not strictly controlled (Córdova-Carrillo 2009).

20.2.7 Climate Change

The coast of the state of Tabasco is particularly vulnerable to climate phenomena and to the future scenarios that are predicted in the context of climate change (CC). Among these, an increase in sea level, together with the present coastal erosion, will lead to a considerable reduction in the surface area of the state of Tabasco for a period of 50–100 years (SERNAPAM 2011). Saltwater intrusion and changes in the salinization of coastal lands have changed the distribution of mangroves, with a decrease in area in some places and an increase in others (Moreno-Cáliz et al. 2009; Valderrama-Landeros et al. 2017). In addition, changes in the edaphological characteristics of productive lands are already affecting agricultural activities with modification of the ideal conditions for certain crops, for which it will be necessary to plan an adaptive conversion for primary productive activities to gradually adapt throughout the systems and regions. If these environmental changes could be carried out effectively, they could be made the most of to extend mangrove cover. Reforestation and restoration programmes have been implemented for the coastal area of the RBPC, and it is expected that they will help/strengthen the natural barrier that mangroves provide, as well as reservoir areas for commercial species of fish and aquatic invertebrates.

As it was stated in previous sections, the state of Tabasco suffered a great environmental transformation and degradation following policies of rural development that focused on agricultural production and oil exploitation, at the expense of a widespread deforestation, the destruction of wetlands and pollution. In view of this, NPAs are considered important as reservoirs of biodiversity (species and their genetic material) and natural resources and for the environmental services they provide for humans. If the trend for consumer-focused development prevails, NPAs will be the last reservoirs of biodiversity, and they will continuously change along with evolutionary processes and following the accelerated changes that will occur as the result of CC (Mansourian et al. 2009).

Among the environmental services that coastal NPAs can potentially provide are a high production of organic matter from plants, natural barriers against storms and hurricanes, protection against coastal erosion, spawning and nursery areas for ecologically and economically important estuarine and marine species, an enhanced recharge of aquifers, regulation of floods and river overflows (Moreno-Cáliz et al. 2009), mitigation processes and a contribution in face of CC, where ample areas with natural vegetation prevent losses and store the carbon present in plants and soil and carbon that would otherwise enter the atmosphere and adaptations (Dudley et al. 2010a, b). Thus, the mostly aquatic and semi-aquatic ecosystems in the RBPC can potentially absorb CO_2 to a greater degree than other ecosystems (Moreno Cáliz et al. 2002). For this reason, adaptation strategies are focused on stopping the deforestation of forests and wetlands and strengthening restoration and reforestation processes in the tropics (Dudley et al. 2010a).

Regarding adaptation, these processes may be seen in the socio-environmental systems and the social groups that live in the RBPC, where adaptation is related to a decrease in vulnerability and a strengthening of the social capital and resilience (Adams and Hutton 2007; Ruiz-Mallén et al. 2015). NPAs can achieve this by managing natural resources and providing environmental services that together may help protect people and face some of the expected CC impacts in the best way possible. This is called an adaptation based on ecosystems (ABE) (Dudley et al. 2010a). To achieve this, an integral management and planning by various sectors and actors are required.

The protection and maintenance of ecosystem services may help people better face the present and future challenges to their wellbeing, regarding the supply of drinking water, access to fishery, agricultural and wildlife resources and control of diseases (Dudley et al. 2010a). These adaptations may help decrease risks in the face of natural events and disasters, as have occurred in the past in the RBPC, such as storms, hurricanes and floods, when the ethnic social composition requires the strengthening of collaboration mechanisms among all sectors and of the arrangements for shared management at the community level (common, community and private lands) that play an active part in the implementation of adaptation and mitigation strategies (Romero-Gil et al. 2000; Barba-Macías et al. 2014a; ECCAP, CONANP 2015). A comprehensive attention to and a sustainable practice of local productive activities, and the improvement of infrastructure and local management capacity, may decrease vulnerability in these socio-environmental systems.

A regionally focused adaptation programme includes an ecological corridor with two NPAs: the RBPC and the area for the protection of flora and fauna Laguna de Terminos (APFFLT). Diverse policies have been implemented in the RBPC since 2010, through subsidies for projects with the local communities to work on strengthening mitigation through ecological restoration and reforestation programmes with a view to increase the surface area of natural vegetation to increase CO_2 sinks and adaptation activities with the purpose of stopping coastal erosion in the state and the changes in the use of the soil that affect the reserve.

Also taking place are several campaigns to provide technical training, economic support and raise awareness for the development of productive projects such as aquaculture and community gardens to strengthen the capacity of the local communities (Morales 2018). In addition, the legal and sustainable use of mangroves (black and white) has been regulated to obtain poles, wood for building and plant firewood and charcoal, among other products (Domínguez-Domínguez et al. 2011). With this type of management (ABE), it is expected that human settlements become better prepared to face climate events and, at the same time, offer them opportunities for a sustainable productive diversification in aid of their local economies.

In view of the described profits, the management of NPAs is considered, in an international context, to be one of the most effective conservation strategies and public policy mechanisms for the strengthening of resilience in natural landscapes and socioecological systems (Cumming et al. 2015). This is the case of the profits that good management may provide ecosystems, species, territories and the productive activities and human settlements within and around the RBPC. The relative stability given by NPAs by their legal protection and governing systems provides them with a potential to serve as management laboratories to create long-term development strategies. Another virtue is the recognition of cultural values and local knowledge that allows the inhabitants to manage their resources with a greater legitimacy and sustainability and to care for nature, thus insuring wellbeing for the present population and future generations.

20.2.8 Management of Adjacent Lands

The reserve is subjected to a high level of social and economic vulnerability due to flooding, a situation that is intensified by a chronic pollution of the soil and water and by changes in the use of the soil. These challenges are shared with APFFLT (Escamilla-Rivera et al. 2014). The importance of the area of influence of the reserve was acknowledged in the management plan of the RBPC, and it was proposed to monitor its physical, biological and social changes.

Activities that are not allowed within the RBPC are carried out in its buffer zone, which generates impacts in the area. This is the case of hunting and fishing, since in certain areas, it is frequent for common land inhabitants adjacent to the RBPC to carry out these activities in the reserve, increasing pressure on the resources (De la Rosa-Velazquez et al. 2017). Pressure from outside the reserve increases as those people do not receive financial support and subsidies from the CONANP to develop alternative productive activities.

Another way in which external forces affect agriculture and ranching in the RBPC is when people that lack resources to sow or keep cattle seek a way to gain from their lands and rent them to ranchers of neighbouring villages (Díaz-Perera et al. 2015). Another threat is the exploitation of hydrocarbons as PEMEX infrastructure exists in the surrounding municipalities.

20.2.9 Other Threats Related to Public and Social Policies

Apart from the impacts generated by the human activities indicated above, other problems are associated with the management of the RBPC. As has been mentioned, there are a great number of primary productive activities beyond the framework of sustainability that are carried out illegally by the local people, and other times are favoured and subsidized by the government. Among these activities, agriculture and ranching are the strongest forces of change in the use of the soil within and outside of the reserve (De la Rosa-Velázquez et al. 2017). In order to counteract these forces, the CONANP provides financing and environmental compensation schemes to prevent non-sustainable productive practices. Since the agricultural sector provides greater subsidies and financing than the incentives they receive from the CONANP, producers chose to continue these practices though they contradict and affect the rules of the reserve. This shows the prevalence of economic interests over the objectives of conservation and sustainable development.

Another aspect related to management is the impoverishment of institutional management capacities within the CONANP. This impoverishment follows a decrease in the federal budget for NPA management throughout the country that which in past decades (2000–2010) meant a historic strengthening of the CONANP, which even gave the Mexican government international recognition, reversed during the last administration (2012–2017). Thus, management capacities have decreased, with a loss of personnel, operative capacity and financing for projects for the protection and restoration and sustainable management of resources. The limited management capacity is the main obstacle for the efficiency of NPAs globally (Watson et al. 2014; Gill et al. 2017).

In this same sense, the lower levels of attention and appreciation of the biological heritage on the part of the present federal administration are also seen in the repeated attempts to promote industrial development within NPAs. For this, changes in the laws and decrees of the reserves are being promoted to decrease the level of protection. With this, the government is trying to open protected lands to the mining, oil and tourism industries. This phenomenon is global and has been observed in at least 50 NPAs of the world, including in countries like Canada, the United Kingdom and Australia (Mascia and Pailler 2011; Symes et al. 2016).

Although attempts to abolish the category of biosphere reserve of the RBPC are not known as yet, the potential risk of opening the reserve to a greater exploitation always exists considering the infrastructure of existing wells and pipelines or the possible find of mining deposits.

The problems within the RBPC are very complex. The management capacity of the CONANP is insufficient to see and to solve all the forces of development that have been indicated. It is also insufficient to solve all the social conflicts regarding land tenure and the poverty and marginalization that prevail in the country, together with a chaotic administration of natural resources that generates contradictory policies. Without doubt, to achieve sustainability and to be able to manage integral projects that help protect biodiversity in the reserve is a challenge, but it will generate opportunities of development for its inhabitants.

20.3 Discussion

The information presented here will contribute to an understanding of how the natural ecosystems in the NPA of the RBPC function and will make it possible to understand landscape processes in order to evaluate global change. The nine threats described here have a significant impact on natural ecosystems, and their effects reach all levels of biological organization. The impact and scope of the effects of the threats can be analysed in three integrated aspects.

20.3.1 Threats at the Spatial or Landscape Level

Threats Please check if edit to sentence starting "Threats at the…" is okay.at the spatial or landscape level are (1) recreational use and management, (2) management of crops and grazing, (3) management of fires, (5) diversion and reservoirs (waterworks) and (8) management of adjacent lands.

The common factor to these threats is the physical space, where different activities related to the use and transformation of the soil and landscape determine gradual effects. The fires started in paddocks, and those induced for hunting purposes result in a loss of connectivity among populations and may prevent access to different habitats during key seasons for certain species (e.g. reproduction, seed dispersal, pollination). This practice has a high impact on the flora and fauna of mangroves, medium and low flooded tropical forests (Sol-Sánchez et al. 2000; Zenteno 2011), rooted emergent hydrophytes (Guerra-Martínez and Ochoa Gaona 2008), shores and dunes.

Among the main threats that affect the health of ecosystems in the RBPC are deforestation, agriculture and ranching. These are the main causes of the loss of habitats, biodiversity, goods and environmental services, and they promote soil erosion and the fragmentation of the ecosystems. Although deforestation is present throughout the basin, it is on the plain where the de-stabilization of the soil, which increases river, sea and wind erosion, is enhanced, at the same time, as a silting up of the water bodies accelerates.

Agriculture is considered incompatible with the reserve, but, as a contradiction, it receives an important support by the state government, favouring exotic crops that have caused the greatest impact regarding the loss of areas of natural habitats and of biodiversity (Challenger and Dirzo 2009). In addition, in spite of their prohibition and as a result of agriculture and ranching, the use of agrochemicals and organochlorines and bad practices of container disposal persist and decrease in water quality. Also, the leaching of these substances may bioaccumulate or biomagnify in some organisms and even reaches humans if they are consumed.

The growth of the human population and the development of infrastructure to solve or mitigate socioeconomic problems are intrinsically related to the problem of conserving the environment. For example, building canals in basins and diverting and containing basins as is favoured by various sectors are the main factors that generate, on the one hand, the expansion of the agricultural frontier with the resulting increase in sedimentation processes and the intrusion of agrochemicals into aquatic ecosystems (SEMARNAP 2000). On the other hand, connections among aquatic ecosystems – originally isolated – allow the free movement of fauna and flora, which may change the genetic composition of certain communities and, in turn, alter diversity.

Human growth per se and its associated services destroy vegetation in medium tropical forests, river communities and wetlands. The construction of houses, without the formation of villages, is considered a high threat from the point of view of the human growth rate and generates a variety of impacts such as a change in the hydrological regime which entails a decrease in water flow and a change in plant structure which depends on the flood pulses associated with these areas, in addition to an increase in the process of erosion in the river deltas which also affects primary productivity on the plain (SEMARNAP 2000).

Finally, ecotourism, promoted by the government, is an alternative to generate "sustainable" jobs for the communities in the RBPC (CONAFOR, CONANP, etc.). Under the premise of "not attempting against biodiversity", the fact that this activity is not regulated within the RBPC generates conflicts among service providers due to the overlap and "invasion" of boundaries related to the use of the rivers. Thus the importance of regulating this activity, in view of the lack of published information that evaluates the impact of ecotourism in NPAs. More so if, "as is the case", there is no adequate management of the waste generated by the activity (cans, bottles, bags, domestic waste, etc.).

20.3.2 Threats with a Functional Approach

Threats with a functional approach among which are (4) introduction of and invasion by invasive exotic species and (6) emission of pollutants.

The introduction of exotic species is no less worrying, mainly as the introduced species displace native species. This is well known in the case of species like the tilapia and herbivore carp, which, however, does not represent a high threat due to its high capture rate, as well as of the molluscs, *Melanoides tuberculata*, *Tarebia granifera* and *Corbicula fluminea*, for which the impact is unknown (Cruz-Ascencio et al. 2003; Rangel-Ruiz et al. 2011; Trinidad-Ocaña et al. 2016). In contrast, the devil fish or armed fish has increased in distribution and abundance during the last years (Barba-Macías et al. 2014b, 2015). Several actions have been implemented for its control and use, one of which is the preparation of feed substituting sardine flour by armed fish flour. This is used to fatten tilapia with very good results, the regulation of its populations and a decrease in their effects on the environment (Cano-Salgado et al. 2018).

The presence and impact of exotic species are more obvious in inland freshwater ecosystems. In the case of fish, the panorama is critical as, of the 510 freshwater species recorded in the NOM-059-SEMARNAT-2001, 169 in the reserve are under some category of risk (69 in danger of extinction, 69 threatened and 20 under special protection). The main causes of their threatened state are the alteration of the habitat (35%), the decrease in water level (34%) and the presence of exotic-invasive species (31%). The relative importance of introduced fish species is high, 115 in the year 2004 (Contreras-Balderas et al. 2004). However, the economic effects of these invasions are being evaluated (Challenger and Dirzo 2009).

20.3.3 Threats with a Global, Multifactorial and Multiscale Approach

Threats with a global, multifactorial and multiscale approach among which are (7) climate change and (9) other threats related to public and social policies.

Stopping or reverting the causes of deterioration in the RBPC may be achieved by joining criteria among the different government and non-government sectors, in order to propose work that minimizes the deterioration of the NPAs and at the same time actions and activities focused on mitigating negative impacts on the structure and functioning of the RBPC, considering that it offers a wide spectrum of values, goods and services.

Another aspect related to management is the impoverishment of institutional management capacities within the CONANP. This impoverishment follows a decrease in the federal budget for NPA management throughout the country. That which in past decades (2000–2010) meant a historic strengthening of the CONANP, which even gave the Mexican government international recognition, reversed during the last administration (2012–2017). Thus, management capacities have decreased, with a loss of personnel, operative capacity and financing for projects for the protection, restoration and sustainable management of resources (La Jornada 2016). The limited management capacity is the main obstacle for the efficiency of NPAs globally (Watson et al. 2014; Gill et al. 2017).

The protection and maintenance of ecosystemic services may help people better face the present and future challenges to their wellbeing, regarding the supply of drinking water, access to fishery, agricultural and wildlife resources and control of diseases (Dudley et al. 2010a). These adaptations may help decrease risks in the face of natural events and disasters, as have occurred in the past in the RBPC, such as storms, hurricanes and floods, when the ethnic-social composition requires the strengthening of collaboration mechanisms among all sectors and of the arrangements for shared management at the community level (common, community and private lands) that play an active part in the implementation of adaptation and mitigation strategies (Romero-Gil et al. 2000; Barba-Macías et al. 2014a; ECCAP, CONANP 2015). A comprehensive attention to and a sustainable practice of local productive activities, and the improvement of infrastructure and local management capacity, may decrease vulnerability in these socio-environmental systems.

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Chapter 21
Diversity, Distribution, and Abundance of Woody Plants in a Dry Tropical Forest: Recommendations for Its Management

Jesús Argumedo-Espinoza, Joaquín Sosa Ramírez, Vicente Díaz-Núñez, Diego R. Pérez-Salicrup, and María Elena Siqueiros Delgado

Abstract Dry tropical forests cover approximately 35% of Mexico's surface. However, in the past 20 years, a substantial proportion of these forests have been lost, placing this country among the first three with highest deforestation worldwide. In Aguascalientes this type of forest is located mainly in the municipality of Calvillo and is also in a process of degradation. We conducted a phytoecological analysis to document the species richness, their abundances, spatial distribution, and overall diversity. We established 26 sites in the forested area of the Sierra Fría Protected Natural Area. We identified 79 species of trees and shrubs belonging to 45 genera and 14 families. The diversity index H′ varies from 3.49 in the best preserved sites to 2.77 in the most degraded sites. The species richness found in this area (N = 79) is similar to that reported for other areas in the dry tropical forests of Mexico. Management strategies are suggested to conserve biological diversity and ecosystem services associated with this forest, considering the aspirations and well-being of the rural communities that own the land where these forests are located.

Keywords Dry tropical forest · Diversity index · Richness · Management

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21.1 Introduction

Forests are the habitat of a considerable number of species, which generate multiple essential services for the functioning of the systems that support the life of the earth (Rendón et al. 2013). Currently, about 80% of the terrestrial ecosystems have been modified by human-related activities, which results in great losses in the number of plant and animal species, which in turn derive in negative consequences for the environmental services ecosystems provide (Rey-Benayas and Bullock 2012).

Mexico is a country rich in natural resources, which is considered one of the five most megadiverse countries (Llorente-Busquets and Ocegueda 2008). According to the Soil and Forest National Inventory (INFyS 2008), ecosystem diversity in Mexico ranges from lowland tropical forests to deserts. These natural communities present different disturbance regimes, both in magnitude and intensity, of which, land use change to agricultural activities is the main cause of degradation (Chazdón 2003; Bullock et al. 2011). Other disturbances that cause strong impacts on ecosystems are the growth of human infrastructure and the expansion of urban areas.

Forest area in Mexico is the 12th most extensive in the world, and the 3rd in Latin America (State of the World's Forests 2012); however, during the past 20 years, it is also within the first three countries with the highest loss of primary forest, following Brazil and Gabon. Likewise, it occupies the seventh place with the largest number of reforested areas (FRA 2010). According to the global assessment of forest resources, by 2010 coniferous forests in Mexico were the most affected natural vegetation type, probably because to the diversity of the geoforms where they are located and the amount of resources that are extracted from them (Challenger 1998; Del Ángel-Mobarak 2012).

Coniferous and oak forests are the most extensive vegetation types dominated by woody plants in Mexico, with 16.4% of the total area of the country (Challenger and Soberón 2008). In terms of biodiversity, lowland tropical forests harbor the greatest species richness (Tilman et al. 2001). Historically, wet forests and seasonally dry forests or dry tropical forests (DTF) covered 35% of Mexican territory (Challenger and Soberón 2008) and hosted at least 33% (824 species) of terrestrial vertebrates and near of 6000 species of vascular plants (Halfter and Ezcurra 1992; Ceballos and García 1995; Rzedowski and Calderón 2013). However, these natural communities have experienced a great variety of human-associated disturbances of different duration, intensity, and frequency (Chazdón 2003), which have generated a strong process of deforestation and annual degradation of between 1.4% and 2% (Masera et al. 1997; Trejo and Dirzo 2000) driven mostly by socioeconomic and demographic factors (Grau and Aide 2008).

Forest disturbances generally cause a spatial mosaic of patches or stands of different shape and structure, which may vary in plant cover and in species richness. However, there are very few studies conducted in this topic worldwide (Hernandez-Oria 2007; Medrano-Cruz 2009). For example, in Costa Rica, Marcano-Vega et al. (2002) found that on average total recovery of abandoned agricultural areas take 25 years. Recently, studies to characterize the dynamics of DTF-dominated landscapes in Mexico have centered in analyzing their structure, spatial arrangement, and floristic composition, in view of the loss of diversity that human disturbances cause in this ecosystem (Martínez-Ramos et al. 2012). An example of this is the case of the Tropical Forest Management project (known by its abbreviation as MABOTRO) where two large study systems were evaluated, the ecological (ecosystem) and the social (sociosystem) systems and their interactions. In the latter, the regional and local knowledge of these ecosystems are highlighted in order to portray the natural capital that this ecosystem provides to society through essential services for local and regional economic development (Castillo et al. 2005; Porter-Bolland et al. 2012).

In Aguascalientes, the largest vegetation distribution of DTF is located in the municipality of Calvillo, in the southwestern portion of the state, although there are a few relict areas in the municipalities of San José de Gracia, Jesús María, and Aguascalientes (IEFyS 2012). In these areas, the DTF is probably the most fragile ecosystem and is threatened mainly by the advance of the agricultural frontier (IEFyS 2012). In these locations studies of vegetation have centered in describing species composition (Siqueiros-Delgado 2008), but the structure and distribution of these forests have not been documented. Previous field work suggests that patches with the most mature vegetation are located in inaccessible sites (La biodiversidad de Aguascalientes: Estudio de Estado 2008). However, in other regions of the state, patches or fragments of different stages of succession have begun to regenerate in the landscape, dominated by the pioneer species such as *Acacia berlandieri* (locally known as carbonera).

On the other hand, Díaz-Núñez et al. (2014) found that DTF vegetation is affected by various organisms such as stem borer insects and parasitic plants and epiphytes. However, when these agents show low levels of damage, they do not pose any risks to biodiversity. The objectives of this study were to describe the composition and diversity of the woody plants of a DTF located in the municipality of Calvillo, Aguascalientes, and suggest management actions that would contribute to their conservation and sustainable use.

21.2 Materials and Methods

21.2.1 Study Area

The study was conducted in 26 sites with DTF vegetation cover in El Terrero de la Labor ejido, located within the Sierra Fria Protected Natural Area, in the municipality of Calvillo, state of Aguascalientes, in Central Mexico. The ejido polygon comprises an area of 5861 ha. (INEGI 2007), of which, the DTF occupies 45% of its total area (Fig. 21.1). It is located within the extreme coordinates: 102°43′58.88″ west longitude and 22°6′4.78″ north latitude and at the southeast end 102°41′24.95″ west longitude and 21°44′27.61″ north latitude.

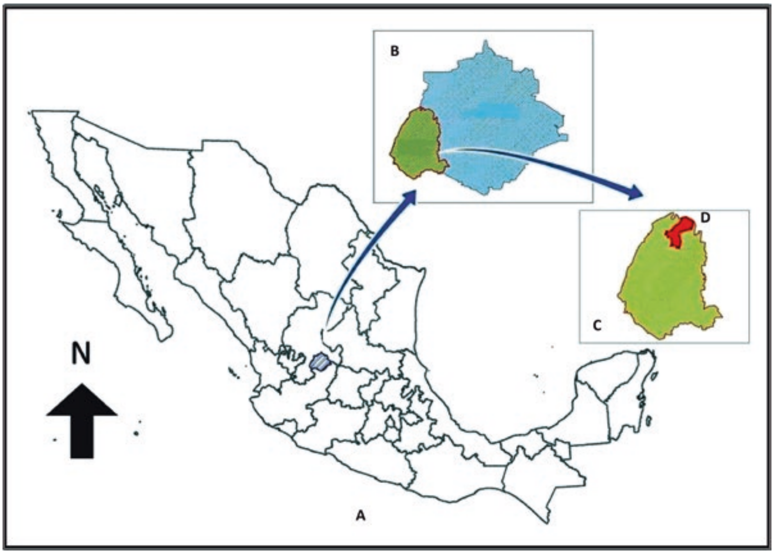

Fig. 21.1 Location of the study area. (**a**) Mexico, (**b**) state of Aguascalientes, (**c**) municipality of Calvillo, and (**d**) El Terrero de la Labor ejido

21.2.2 Selection of the Study Sites and Sampling Design

We used a stratified sampling design system (Daget and Godron 1982). Sampling strata were delimited based on geoforms, slope, exposure, and altitude. To characterize geoforms, three criteria were used: concave, convex, and flat terrain. A concave geoform was defined when the slope ranged between 10% and 25%, which usually corresponded to ravines and small depressions. When the sites had a slope between 25% and 60%, they were characterized as convex sites. Flat terrains had slopes <10%. Solar exposure was defined using an exposure map made with a geographic information system from a 2008 Spot® satellite image and a digital elevation model (MDE). Only the main cardinal points (north, south, east, and west) were considered. To locate the altitudinal strata, the contours of the zone defined from the MDE were used. Subsequently, a grid map was developed for the identification of the sampling areas (Fig. 21.2).

21.2.3 Selection and Characterization of Sites to Quantify Composition and Abundance of Woody Species

We established 26 sites to quantify phytoecological inventories, distributed in the landscape according to the abovementioned sampling system. At each point, the projected coordinates of the site were taken with GPS Garmin 48 XL line in UTM

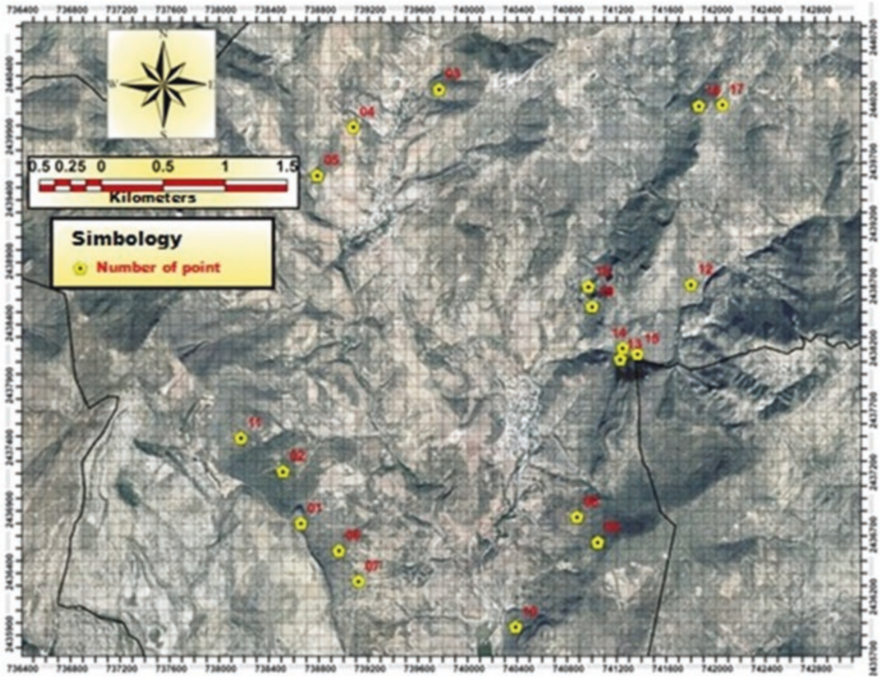

Fig. 21.2 Geographic representation of dry tropical forest and the sampling points in El Terrero de la Labor ejido in the municipality of Calvillo, Aguascalientes

format, zone 13 North and with reference Datum WGS84 and with accuracies of 5–12 m with differential kinematic adjustment (WAAS). Subsequently, the points were placed on a SPOT 2010 satellite image (Fig. 21.3). Site variables considered were the slope (%), solar exposure, physiography of the terrain, intensity and type of use, and canopy coverage.

Slope at each sampling site was obtained by direct field measurement with a Bruntton clinometer with a precision of +/− 2° of variation for each 100 m of length. This data in turn was contrasted with the data obtained from the digital elevation model with precision of 1–2 m in the Z value. Five classes were used to define the slope: (1) <10%, (2) 11–30, (3) 31–50, (4) 51–70, and (5) >70. Exposure to solar radiation was estimated considering the cardinal points north (N), south (S), east (E), and west (O), as well as their combinations.

The altitude of each site was obtained directly in the field with the support of a GPS with barometric adjustment to reduce the effect of mathematical variation of the geoid model and with precision of 1–3 m. This was compared with the data obtained from the prospecting of points against elevation level curves obtained from the digital elevation model to reduce the potential errors of direct measurements.

The physiography of the terrain was characterized considering flat terrain (slope <10%), steep (without slope), medium slope (10–25%), and high slope (>60%). The exposure of the sites was quantified with a compass, and the magnetic north was

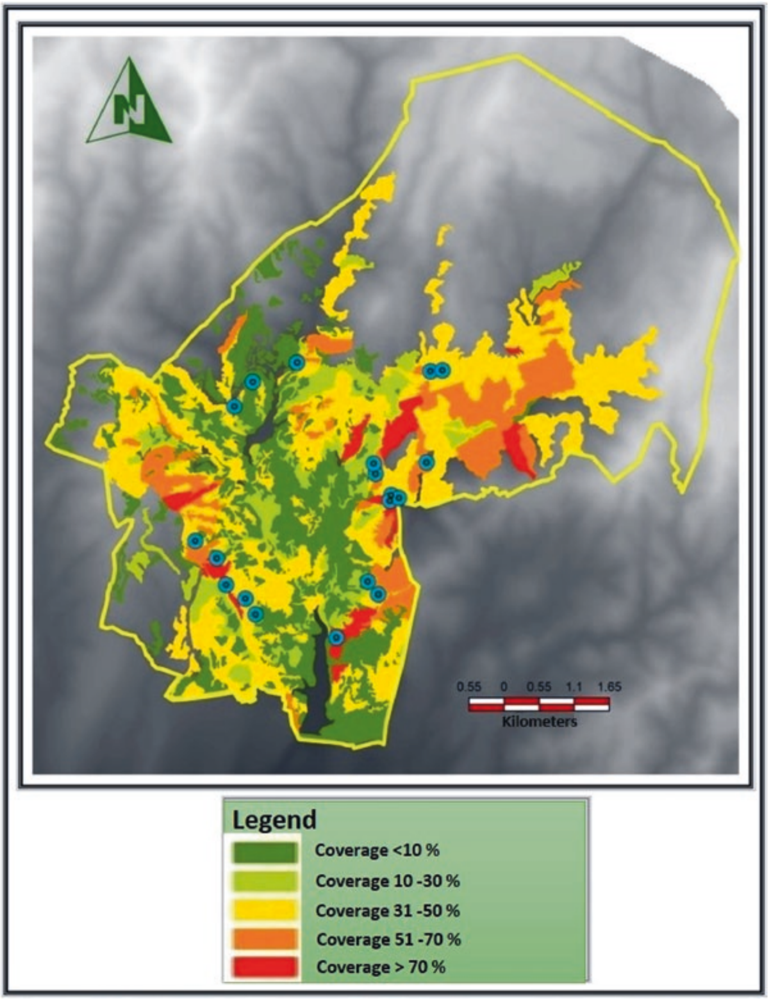

Fig. 21.3 Hypsographic model of El Terrero de la Labor ejido polygon and distribution of the sampling points in the DTF

taken as reference for its definition in the previously defined ranges. Exposure for each stand of the sampling site was also analyzed along with the digital model of exposures generated from the digital elevation model.

Other characteristics considered in the description of the sites were the degree of modification (i.e., transformation of geographical space, introduction of species), its intensity (light, medium, and overexploited), as well as the type of use by local inhabitants (hunting, grazing, gathering, etc.) (Table 21.1).

Table 21.1 Distribution of samplings sites according to the proposed design

Topographic position											
Elevation levels	Concave					Convex					
	Covers					Covers					
	%										
	<10%	11–30	31–50	51–71	>71	<10	11–30	31–50	51–71	>71	Total
1800–1900	0	0	0	0	1	0	1	0	3	0	5
1901–2000	0	0	0	0	0	1	1	3	5	1	11
2001–2100	0	0	0	0	0	1	1	2	2	0	6
>2100	0	0	0	0	0	0	0	0	4	0	4
Total	0	0	0	0	1	2	3	5	14	1	26
Total inventories		26									

21.2.4 Floristic Composition

To describe species composition, we used a sampling design based on nested plots in an area of 1024 m^2 in each inventory, using the criteria of the minimum area (Daget and Godron 1982). We started with a plot of 1 × 1 m in a direction perpendicular to the slope in which all present species were recorded. Subsequently, the plot was increased in size to 2 × 1, 2 × 2, 2 × 4, 4 × 4 m, etc. registering the new species for each increment in the area of the squares until reaching the maximum extension (i.e., 32 × 32 m = 1024 m^2), to obtain an area/species curve. We then identified the area in which the present species stabilized. This sampling method increased the probability of finding rare species as the area increased, an effect known as rarefaction (Begon et al. 2006).

Identification of species was estimated in the field by morphological characters described in previous studies. Specimens that could not be identified in the field were collected and later identified in the Herbarium of the Autonomous University of Aguascalientes (HUAA).

21.2.5 Distribution and Abundance of Species in the DTF

We used the linear intercept survey method (Canfield line). A 100-m-long line was perpendicular to the slope, starting at the GPS coordinates of the sampling site, and then intersection lines were defined where individuals of DTF species were counted at constant intervals of 1 m. Shrub and tree individuals were categorized into five height classes 0–1 m, 1.1–2 m, 2.1–4 m, 4–8 m, 8–15 m, and >16 m. For each class we measured canopy cover of each species by measuring the perpendicular projection of the crown and the frequency of species. To estimate crown cover, the following formula was used:

$$\text{Cover}(\text{C}) = \frac{\Sigma\,\text{length of individuals of species i}}{\text{total length of intersections}} \times 100.$$

To estimate frequencies, we used the formula:

$$\text{Frequency}(\text{F}) = \frac{\begin{array}{l}\Sigma\,\text{of number of times that individuals of the species}\\ \text{intercepted by the line}\end{array}}{\Sigma\,\text{total species intercepted}} \times 100.$$

21.2.6 Data Analyses

Species composition was estimated through the identification of the species found in each of the sampling plots. To find a limit on the number of samples and to reduce the possibility of under- or over-sampling, we conducted a rarefaction analysis. The Shannon-Wienner alpha diversity (H′) was calculated for each of the sites and for each altitudinal level using the Species Richness and Diversity software, considering that there could be variation in diversity according to the change in environmental conditions in temperature and precipitation as mentioned in the standard atmospheric index (decrease of 0.6 °C/100 m altitude).The formula of the Shannon index is:

$$H' = -\sum_{S}^{i=1} p_i \log_2 p_i$$

where:

- S – Total number of species (species richness)
- P_i – Proportion of individuals of species i in respect to total of individuals (i.e., relative abundance of species i): $\frac{n_i}{N}$
- n_i – Number of individuals of species i
- N – Total number of individuals of all species

The index considers the number of species present in the study area (species richness) and the relative number of individuals of each of those species (abundance).To estimate replacement rates of species, Whittaker's β diversity was computed, using the diversity found for each altitudinal level analyzed as reference.

$$\beta = \frac{s}{\alpha - 1}$$

where:

β = Whittaker's β diversity
S = Total number of species in samples
α = Mean number of species in samples

21.3 Results

21.3.1 Species Composition

We identified 79 species of trees and shrubs, within 45 genera and 14 families (see Table 21.2).

Table 21.2 List of species identified in the dry tropical forest of Terrero de la Labor ejido, Calvillo, Ags

Species	Family	Local name
Acacia berlandieri Benth.	Fabaceae	Carbonera
Acacia farnesiana (L.) Willd.	Fabaceae	Tepame
Acacia pennatula (Schltdl. & Cham.) Benth.	Fabaceae	Huizache o Cascalote
Agave angustifolia Haw.	Asparagaceae	Agave espadín
Albizia plurijuga (Standl.) Britton & Rose	Fabaceae	Tepeguaje blanco
Alnus acuminata Kunth	Betulaceae	Aile
Amelanchier denticulata (Kunth) K. Koch	Rosaceae	Duraznillo
Amphipterygium molle (Hemsl.) Hemsl. & Rose	Anacardiaceae	Cuachalalate
Asclepias linaria Cav.	Apocynaceae	Algodoncillo
Ayenia mexicana Turcz.	Sterculioideae	
Baccharis heterophylla Kunth	Asteraceae	Escobilla
Bouvardia multiflora (Cav.) Schult. & Schult. f.	Rubiaceae	Clavelito
Brickellia veronicifolia (Kunth) A. Gray	Asteraceae	Orégano de monte
Buddleja cordata Kunth	Buddlejaceae	Tepozán blanco
Buddleja sessiliflora Kunth	Buddlejaceae	Tepozán verde
Bursera bipinnata Donn. Sm.	Burseraceae	Lantrisco
Bursera fagaroides (Kunth) Engl.	Burseraceae	Venadilla
Bursera penicillata (DC.) Engl.	Burseraceae	Arbol de chicle
Calliandra eriophylla Benth.	Fabaceae	Calandria
Castilleja tenuifolia M. Martens & Galeotti	Scrophulariaceae	Hierba del cáncer
Cedrela dugesii S. Watson	Meliaceae	Cedro
Ceiba aesculifolia (Kunth) Britten & Baker f.	Malvaceae	Pochote
Celtis caudata Planch.	Ulmaceae	Capulincillo
Celtis pallida Torr.	Ulmaceae	Vara en cruz
Chusquea sp.	Poaceae	Camalote
Colubrina triflora Brongn. Ex G. Don	Rhamnaceae	Algodoncillo

(continued)

Table 21.2 (continued)

Species	Family	Local name
Cordia sonorae Rose	Boraginaceae	Amapa o Vara prieta
Croton ciliatoglandulifer Ortega	Euphorbiaceae	Algodoncillo
Dasylirion acrotrichum (Schiede) Zucc.	Asparagaceae	Sotol
Dodonaea viscosa Jacq.	Sapindaceae	Jarilla
Erythrina flabelliformis Kearney	Fabaceae	Colorín
Eupatorium sp.	Asteraceae	Copalillo
Eysenhardtia polystachya (Ortega) Sarg.	Fabaceae	Palo azulo o Varaduz
Eysenhardtia punctata Pennell	Fabaceae	Palo cuate
Ferocactus histrix Lindsay	Cactaceae	Biznaga costillona
Ficus petiolaris Kunth	Moraceae	Ficus silvestre
Forestiera phillyreoides (Benth.) Torr.	Oleaceae	Palo blanco
Fraxinus purpusii Brandegee	Oleaceae	Saucillo
Gymnosperma glutinosum (Spreng.) Less.	Asteraceae	Cola de zorra
Heliocarpus terebinthinaceus (DC.) Hochr.	Meliaceae	Cicuito o Cuero de indio
Ipomoea murucoides Roem. & Schult.	Convolvulaceae	Palo bobo
Iresine sp.	Amaranthaceae	Cola de zorra
Jatropha dioica Sessé	Euphorbiaceae	Sangregrado
Koanophyllon solidaginifolium (A. Gray) R. M. King & H. Rob.	Asteraceae	Caballito
Karwinskia humboldtiana (Schult.) Zucc.	Rhamnaceae	Coyotillo
Leucaena esculenta (Moc. & Sessé ex DC.) Benth.	Fabaceae	Guaje rojo
Lippia inopinata Moldenke	Verbenaceae	Palo oloroso
Lysiloma acapulcense (Kunth) Benth.	Fabaceae	Ébano o Palo fierro Tepeguaje
Lysiloma microphyllum Benth.	Fabaceae	Tepeguaje
Mammillaria bombycina Quehl	Cactaceae	Biznaga de seda
Mammillaria sp.	Cactaceae	Biznaga
Manihot caudata Greenm.	Euphorbiaceae	Pata de gallo
Mimosa monancistra Benth.	Fabaceae	Gatuño o Uña de gato
Mimosa sp.	Fabaceae	Huizache
Myrtillocactus geometrizans (Mart. ex Pfeiff.) Console	Cactaceae	Garambullo
Montanoa leucantha (Lag.) S.F. Blake	Asteraceae	Talacao o Vara blanca
Opuntia leucotricha DC.	Cactaceae	Nopal chaveño o duraznillo
Opuntia robusta J.C. Wendl.	Cactaceae	Tuna tapona
Opuntia sp.	Cactaceae	Nopal
Opuntia streptacantha Lem.	Cactaceae	Nopal cardón
Perymenium mendezii DC.	Asteraceae	
Pistacia mexicana Kunth	Anacardiaceae	Lantrisco
Pittocaulon filare (McVaugh) H. Rob. & Brettell	Asteraceae	Palo loco
Plumbago pulchella Boiss	Plumbaginaceae	Chilillo medicinal
Plumeria rubra L.	Apocynaceae	Flor de mayo

(continued)

Table 21.2 (continued)

Species	Family	Local name
Prosopis laevigata (Humb. & Bonpl. ex Willd.) M.C. Johnst.	Fabaceae	Mezquite
Ptelea trifoliata L.	Rutaceae	Naranjo agrio o Zorrillo
Quercus laeta Liebm.	Fagaceae	Roble blanco
Salvia mexicana L.	Labiatae	Tlacote
Salvia sp.	Labiatae	Salvias
Stachys coccínea Ortega	Labiatae	Mirto
Stenocereus queretaroensis (F. A. C. Weber) Buxb.	Cactaceae	Pitahaya
Tecoma stans (L.) Juss. ex Kunth	Bignoniaceae	Tronadora
Trixis angustifolia DC.	Asteraceae	Vara verde
Verbesina serrata Cav.	Asteraceae	Vara blanca
Viguiera quinqueradiata (Cav.) A. Gray ex S. Watson	Asteraceae	Vara amarilla
Wimmeria confusa Hemsl.	Celastraceae	Algodoncillo
Yucca filifera Chabaud	Asparagaceae	Palma
Zanthoxylum fagara (L.) Sarg.	Rutaceae	Rabo lagarto

The best represented families were Fabaceae (13 genera), Asteraceae (11 genera), and Cactaceae (9 genera) (Fig. 21.4).

The genera better represented were *Opuntia* ($n = 4$ spp.), *Acacia* ($n = 4$ spp.), and *Bursera* ($n = 3$ spp.). The genera *Bursera*, *Opuntia*, and *Salvia* are also important (Fig. 21.5).

Of the 79 species identified, 8 are distributed in more than 70% of the plots of El Terrero de la Labor ejido. The species with the greater distribution are the *Myrtillocactus geometrizans* (garambullo), *Ipomoea murucoides* (palo bobo), *Eysenhardtia polystachya* (varaduz), *Bursera fagaroides* (venadilla), and *Forestiera phillyreoides* (palo blanco) (Fig. 21.6), which were located in 96%, 92%, 90%, 88%, and 86% of the plots, respectively, assuming that the sampling sites are representative of the entire landscape.

On the other extreme, the rarest species were *Plumeria rubra*, *Ficus petiolaris*, and *Fraxinus purpurea*. The first species was only located in one site, while the last two were only found in two and three sampling sites, respectively. Their low frequency could be associated to their presence in mid-statured forests.

In the DTF of El Terrero de la Labor, the most abundant species belonged to five different genera, of which the most important are *Lysiloma microphylla* (tepeguaje), *Ipomoea murucoides* (palo bobo), and *Bursera fagaroides* (venadilla) (Fig. 21.7). In the case of *Ipomoea murucoides*, it occupies the second place in both distribution and abundance (see Fig. 21.6).

We built and analyzed the species accumulation curve to evaluate whether sampling intensity was sufficient (Fig. 21.8). We observed a first species accumulation peak between the first three plots, then another peak at the sixth plot, one more at 6, and then at 12, after which the curve increased very gradually.

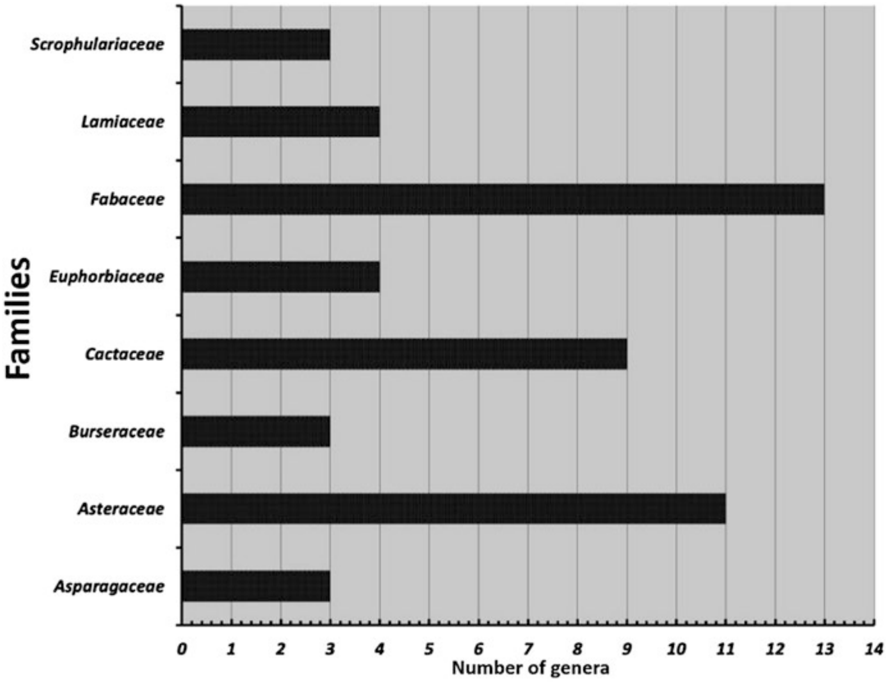

Fig. 21.4 Families and number of genera present in the DTF of El Terrero de la Labor

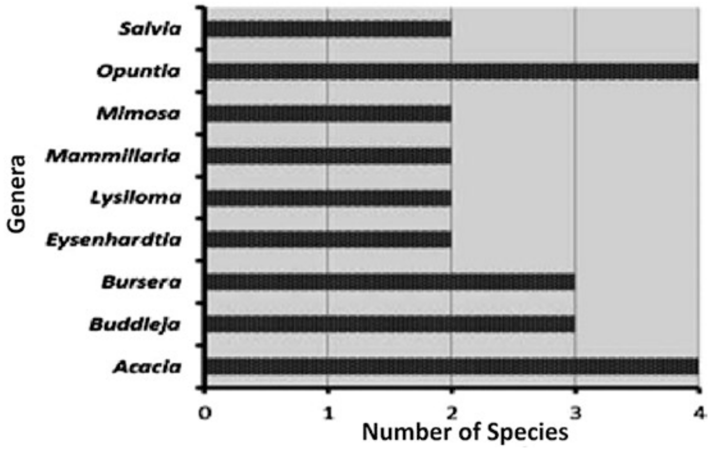

Fig. 21.5 Distribution of genera with greater representation in the DTF landscape of El Terrero de la Labor

Rarefaction estimates the species richness from the results of the sampling effort and shows the relationship between the maximum effort and the number of species to reduce the bias between the number of samples and the total area of the territory. In the case of the DTF of the Terrero de la Labor, we observed that the maximum

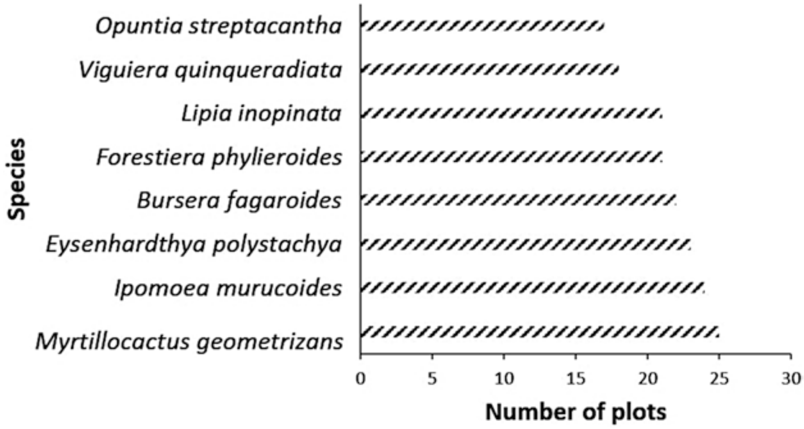

Fig. 21.6 Species best represented in the DTF of El Terrero de la Labor ejido

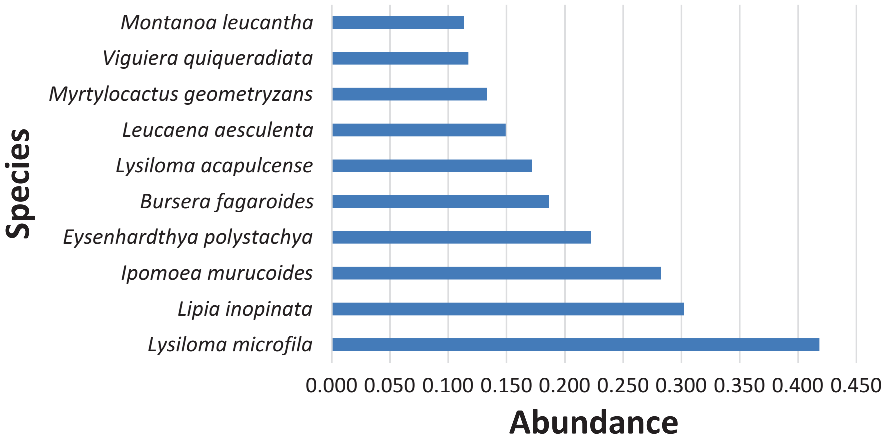

Fig. 21.7 List of species with the highest abundance in El Terrero de la Labor ejido

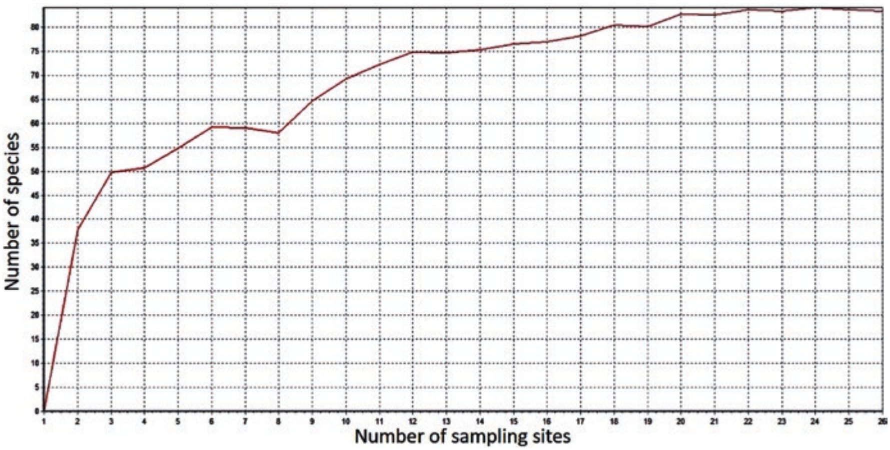

Fig. 21.8 Species accumulation curves in sampling sites of DTF in El Terrero de la Labor ejido

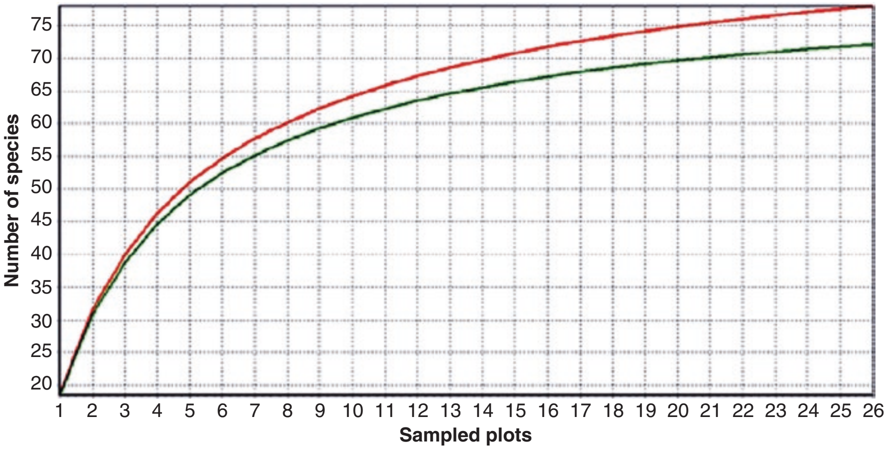

Fig. 21.9 Rarefaction curve that describes the relation between the number of species and the number of sampled plots. The red line represents the maximum species expected in the samples, and the green line represents the species encountered in the samples

species gain was found in the first 12 samplings. After the 22 sample, the gain in number of species is minimal, so there is stabilization in terms of diversity (Fig. 21.9). The species located from after the stabilization of the curve can be considered as "rare," although this requires an analysis of Euclidean distances.

21.3.2 Biodiversity of DTF

The H′ diversity found in the DTF of El Terrero de la Labor ejido is constant. The highest diversity index found was 3.49 in two of the 26 analyzed sites, which apparently are well-conserved sites. On the contrary, three sites had the lowest H′ diversity index with 2.77 (Table 21.3). Although there are apparently no differences, the highest diversity indexes are located mainly in ravines and north-facing exposures and in locations with difficult access.

Although in the analyzed landscape the highest diversity was observed 1950 and 2000 masl, there is no clear difference between the different ranges analyzed (Table 21.4). When we analyzed the effect of slope, the highest diversities are located on slopes greater than 40%, possibly because of the steepness of the terrain and its difficult access for livestock (Table 21.5 and Fig. 21.10).

21.4 Discussion

The loss of biodiversity is one of the environmental problems that has aroused a broad global interest in the last two decades (Tilman et al. 2001). Some of the main causes for biodiversity loss are associated to human activities, either directly

Table 21.3 Diversity of woody species associated with the dry tropical forest of Calvillo, Aguascalientes

Site	H′	Variance	Site	H′	Variance
1	3.2189	0.0192	14	3.2958	0.017833
2	2.9444	0.024931	15	2.8332	0.027682
3	3.0445	0.022676	16	3.3322	0.017219
4	2.7726	0.029297	17	3.1781	0.019965
5	3.3322	0.017219	18	3.3322	0.017219
6	2.8332	0.027682	19	3.2958	0.017833
7	2.3979	0.041322	20	3.091	0.021694
8	2.8332	0.027682	21	2.9444	0.024931
9	3.4012	0.016111	22	2.6391	0.033163
10	3.4012	0.016111	23	2.7726	0.029297
11	3.2581	0.018491	24	3.2581	0.018491
12	3.2581	0.018491	25	3.4012	0.016111
13	3.4965	0.014692	26	3.3673	0.016647

Table 21.4 Average H′ diversity indices associated to different altitudinal ranges in the DTF of El Terrero de la Labor ejido

Elevation levels	Number of sampled sites	H′
1851–1900	7	3.08
1901–1950	5	2.57
1951–2000	7	3.60
2001–2100	5	3.14
>2100	2	3.25

Table 21.5 Diversity indexes associated to different slopes of the sites

Slope range	Number of sampled sites	H′
0–9%	6	2.94
9–25%	3	2.88
26–37%	5	2.92
37–49%	4	3.26
49–64%	5	3.34
>65%	3	3.39

(overexploitation) or indirectly (habitat alteration), although there is generally an interaction between them. The media have made an importance such that both government and private initiatives, as well as the society at large, consider the funding of conservation programs a priority. The basis for an objective analysis of biodiversity and its change lies in its correct evaluation and monitoring.

Studies on biodiversity measurement have focused on finding parameters to characterize as an emerging property of ecological communities. However, communities are not isolated in a neutral environment. In each geographical unit and in

Fig. 21.10 Images that represent the diversity of vegetation of the dry tropical forest in El Terrero de la Labor ejido. (**a**) Landscape dominated by representative vegetation of the tropical dry forest (*Lysiloma acapulcense*, *Manihot caudata*, and *Leucaena esculenta*, among others); (**b**) presence of *Myrtillocactus geometrizans* (locally known as garambullo), one of the best represented species in the dry tropical forest; (**c**) an example of *Manihot caudata* (locally known as jaboncillo) at the end of the leaf development cycle. (Photographs courtesy of Vicente Díaz Núñez, Joaquín Sosa Ramírez, and Jesús Argumedo Espinoza)

each landscape, there are a variable number of communities. Therefore, to understand the changes of biodiversity in relation to the structure of the landscape and to separate the alpha, beta, and gamma components (Whittaker 1972) of biodiversity can be very useful, mainly to measure and monitor the effects of human activities (Halffter 1998).

The measurement of biodiversity has been an issue widely addressed at different scales, ranging from the specific richness (Llorente-Busquets and Ocegueda 2008) to the possible effects of different factors on some species (Álvarez-Romero et al. 2008; Calderón-Aguilera et al. 2012).

Species richness in DTF is generally lower than in humid tropical forests (Gentry 1995), although higher than in temperate mountain forests (Meave et al. 2006). Species richness reaches its closest peak in Ecuador and gradually decreases toward higher latitudes; however, in the case of the DTF of the western region of Mexico, the species richness is not only abnormally high but also contains a large endemic component. Some studies conducted in the DTF of Mexico include information on vegetation types that are not really typical of tropical climates, because the limits coincide with political-administrative borders or physiographic units, but not with climatic units. The typical vegetation of the dry tropics can be dominated by trees, bushes, or grasses, blurring the correlation between vegetation types and precipitation (Gilliespie et al. 2000; Trejo and Dirzo 2000).

The DTF is dominated by relatively short trees, most of which lose all their foliage in the dry season. In this community, herbaceous, thin, woody, and climbing vines are common, but thick epiphytes and woody lianas are less abundant and diverse than in moist or wet forests (Challenger 1998; Pineda-García et al. 2007). Diversity is generally higher without clear dominance by a single species, to the point that many of them are rare (Durán et al. 2006). In this ecosystem type, it is common to identify genera such as *Bursera*, *Lonchocarpus*, *Lysiloma*, and *Jatropha*, as well as emergent columnar cacti (Challenger 1998; Pennington and Sarukhán 1998). The presence of slow growth and long-lived plants, such as succulent cacti, suggest that this vegetation is not normally subject to fire disturbances. Despite these similarities, the DTF is very variable in the structure and composition in different regions of the country.

Species richness found in the DTF of El Terrero de la Labor ejido ($N = 79$) is similar to the numbers reported by Trejo (2005), where she points out that on average the dry tropical forest in Mexico is home to around 74 species with a DAP≥ 1 cm in 0.1 ha. However, some species considered as "rare" in the ravines and better conserved sites that are indicative of medium statured forest (i.e., *Amphipterygium molle*) were found in the analyzed area, suggesting that at some time this ecosystem had a greater representation in the landscape.

The analysis of diversity, distribution, and abundance associated with the TDF of El Terrero de la Labor ejido is one of the first efforts to document the natural heritage of this ecosystem. Previously, only partial floristic studies had been carried out that described mainly the type of dominant vegetation and some important species, but there were gaps in relation to the ecology of plant communities (Biodiversity in Aguascalientes: State Study, 2008). On the other hand, other studies mentioned some factors related to the mortality of these natural communities (Díaz-Núñez et al. 2014), but there is no information on the diversity of vegetation that reflects the true importance of the dry tropical forest.

The information presented in this study constitutes a starting point for the implementation of several studies and programs that allow on the one hand the conservation of plant diversity and on the other the restoration of vegetation with native species of the dry tropical forest.

21.5 Implications for Management of Dry Tropical Forests

The better conserved DTF in the state of Aguascalientes is located in the municipality of Calvillo. However, there are some relicts in the municipalities of Jesús María, San José de Gracia, and Aguascalientes (Díaz-Núñez et al. 2014). The present study on the diversity of woody plants in the DTF was carried out in a polygon of 5861 ha; however, it can be considered that this is a representative of the ecological, environmental, and structural conditions of the natural communities that are distributed in this ecosystem, so it is useful to suggest management strategies that, on the one hand, conserve the biological diversity of DTF and the ecosystem services they provide and, on the other hand, derive in economic benefits to rural communities that own the land.

Although there is a phytosanitary diagnosis of the organisms that affect the arboreal and shrubby communities (Díaz-Núñez et al. 2014), it is necessary to deepen the analysis to identify their interactions and the effect they have on the landscape, in order to suggest control strategies to reduce vegetation mortality or, if this is the case, understand the recycling of nutrients and the natural regeneration of the sites associated with tree mortality (Keeley 1999) (Fig. 21.11).

On the other hand, according to information presented and compared with other studies in temperate mountain forests and thorny scrub, the DTF is the most diverse ecosystem in vegetation in the state of Aguascalientes (Díaz et al. 2012; Sosa-Ramírez et al. 2011). However, it also the most fragile as a consequence of the agricultural frontier associated to the establishment of guava, citrus, avocado, and, in the best cases, agroforestry systems, which is why it is necessary to protect them through different schemes. One example is the payment for environmental services

Fig. 21.11 Work team analyzing the vegetation structure of a site dominated by dry tropical forest elements. (Photograph courtesy of Jesús Argumedo Espinoza)

sponsored by the National Forestry Commission. Although these payments are already applied in some locations, it is necessary to expand it due to its importance, considering that this ecosystem harbors protected species according to the Official Mexican Standard NOM-059-SEMARNAT-2010. Some of these protected species include *Mammillaria bombycina* and *Laelia speciosa*, among others. Likewise, there are some indications of the presence of the golden eagle (*Aquila chrysaetos*) and the flag bird (*Trogon elegans*), both representatives of the state.

Although the literature mentions that the DTF is a very dynamic ecosystem (Chazdón 2003), we found sites in El Terrero de la Labor ejido that have not recovered their original canopy cover and number of arboreal species. So we suggest the need to restore native species in the area, ideally with individuals with at least 3 years of establishment to avoid mortality. We suggest that these efforts should consider the uses of local inhabitants to increase the value of forests in the eyes of their owners.

Government agencies have developed productive projects in these areas, including the establishment of production units of wild oregano (*Origanum vulgare*) in agricultural areas outside the polygon of the area considered as protected. Although *O. vulgare* is not a native species, it is hoped that the increase value of agricultural land would decrease the pressure on remaining DTF.

A section of the studied polygon is located within the area known generically as "Sierra Fría," a space decreed as a Protected Natural Area by the state of Aguascalientes (Government of the State of Aguascalientes 1994), where different activities, both intensive and extensive, are carried out, among them, diversified livestock through Management Units for the Conservation of Wildlife (UMAs, by its acronym). Therefore a management proposal would expand the UMAS universe to develop a regulated hunting of native species, such as *Meleagris gallopavo* (wild turkey), *Odocoileus virginianus Couessi* (whitetail deer), and *Tayassu tajacu* (collared peccary). Similarly, these management alternatives could include the photographic hunting of emblematic species such as *Trogon elegans* (flag bird) to name a few. These activities could also include the establishing of spaces and trails for observation and recreational routes, limiting the extractive and non-extractive use to reduce the pressure on the system (Martín-Clemente 2017). Currently, two UMAs are registered that provide an alternative of income for local inhabitants, but other UMAs could follow.

The mentioned proposals and others that can be generated through participatory workshops would constitute an excellent mechanism to conserve the DTF or even to increase its cover in sites that have not yet been highly disturbed and in which still hold relicts of well-conserved vegetation.

21.6 Conclusions

We identified a total of 79 arboreal and shrub species in the polygon of El Terrero de la Labor ejido. The best represented families are the Fabaceae and Asteraceae. The species with greater distribution are the *Myrtillocactus geometrizans* (garambullo), *Eysenhardtia polystachya* (varaduz), and *Lippia inopinata* (palo oloroso), while the most abundant species are *Lysiloma microphylla* (tepeguaje), *Ipomoea murucoides* (palo bobo), and *Bursera fagaroides* (venadilla). According to the analysis of Euclidean distances, the most rare species are the *Amphipterygium molle* (cuachalalate) and *Ficus petiolaris* (wild ficus). The highest H′ is 3.39, which is located in the range of 2050–2100 masl and on slopes of 30–50%.

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Chapter 22
Conservation of Biodiversity vs Tourism and Fishing at the Archipelago Espiritu Santo in the Gulf of California

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Abstract This chapter covers anthropogenic pressure at the Espiritu Santo Archipelago and its protected marine area in the Gulf of California through the analysis and location of productive activities, considering the biodiversity of the protected natural area (PNA). The results indicate that the state of conservation in general of the PNA is good. However, of all activities tourism represents the sector providing the greatest pressure on the archipelago complex, because it is a growing activity. Although tourism being carried is ecotourism and adventure tourism, this activity still nevertheless produces pollution, disturbance of flora and fauna, introduction of exotic species, and problems with the fishing sector by the use of common areas.

Keywords Biodiversity · Protected areas · Tourism · Fishing · Conservation

22.1 Introduction

Biodiversity provides benefits to society in different ways, for example, through eco-services and products that can be obtained from ecosystems, either by promoting environmental services or by consumptive and non-consumptive use of species, among other sources of value, which include the economic valuation of ecosystems (Costanza et al. 1997). One of the strategies being carried out by the government of Mexico in order to promote the conservation of biodiversity in the country and stop

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the deterioration processes that threaten it has been the creation of regions denominated as protected natural areas (PNAs). Through the establishment and management of these PNAs, the government seeks together with society to find new forms of organization, cooperation, and development that guarantee the conservation of nature.

In Mexico, the General Law of Ecological Balance and Environmental Protection (LGEEPA, as known by its Spanish acronym) (DOF 2017), Article 3, Section II, defines PNA as a region of national territory where Mexico as a nation exercises its sovereignty and jurisdiction, and it has been determined that its natural environmental landscape has not been significantly disturbed by the activity of man, and thus it can be subject to a protection regime.

The National Commission of Protected Natural Areas (CONANP) administers 181 natural areas of federal character representing more than 90 million hectares. In the state of Baja California Sur (BCS), several protected natural areas of federal character have been declared. There are at present two biosphere reserves, El Vizcaino and Sierra de la Laguna; three national parks, Cabo Pulmo, Loreto Bay area, and the National Marine Park of the Espiritu Santo Archipelago (PNZMAES, as commonly known by its Spanish acronym); and three areas of protection of flora and fauna that include Cabo San Lucas, Balandra, and islands and islets of the Gulf of California (APFFIGC, by its Spanish acronym); these include about 900 islands which are part of the Espiritu Santo Island Complex (known in Spanish as CIES) (CONANP 2016). In addition, the state of BCS has declared as a state ecological reserve the riparian basin and estuary of San José del Cabo, as well as eight Ramsar sites in the state (Arizpe and Arizpe 2015).

Moreover, the islands are recognized as areas of notable biodiversity, as natural evolutionary laboratories with biological conservation prospects. Due to the relative isolation of island ecosystems, they are particularly vulnerable to anthropogenic activities. In contrast, to other regions of the world, these in the Gulf of California are also relatively well conserved (CONANP 2014). There are about 40 islands and islets in the Gulf of California, and BCS is recognized as one of the states of Mexico that has more islands and/or islets along its coast (Maldonado 1997; CONANP 2014). Due to the extension and diversity of these islands, planning mechanisms are necessary to consider the problems and characteristics of these islands or archipelagos, such as CIES (CONANP 2000, 2011).

CIES is composed of Espiritu Santo Island and Partida Island as well as the islets of La Ballena, El Gallo, and La Gallina. Presently, there is great interest for its conservation due to the threat of intense anthropogenic pressure taking place. CIES ecosystems are valued for their outstanding biological biodiversity as well as for tourism (CONANP 2006). Due to these characteristics of the CIES, there have been conflicts between users, scarcity of resources, landscape deterioration, pollution, development and conservation pressures, and some loss of biodiversity (CONANP 2000; Cervantes Villegas 2012).

According to the Directorate of Culture for Conservation of the APFFIGC in BCS through CONANP, CIES houses, in its islands and islets as well as in its adjacent marine area PNZMAES, a high number of species of flora and fauna under some status of protection and endemic species, especially of reptiles and mammals. In addition, due to its proximity to the coast and to the abundance of its marine resources, CIES and PNZMAES represent a site of economic importance for the city of La Paz, due to the fishing and tourism activities carried out (CONANP 2011). However, it has been observed that these human activities have produced environmental problems. Poaching and the use of prohibited fishing gear affect the sustainability equilibrium of the marine environment. Human settlements and regular visits produce, among other impacts, pollution, introduction of exotic species, and disturbance of wildlife (CONANP 2000; Cervantes Villegas 2012).

22.2 Study Area

On the east coast of the state of Baja California Sur (BCS), Espiritu Santo Island Complex (known in Spanish as CIES) (CONANP 2016) is located between 24° 24′ and 24° 36′ north latitude and 110° 18′ and 110° 27′ west longitude; the area of influence of the complex comprises the bay and the municipality of La Paz, where the city is separated by only 25 km in a straight line (CONANP 2000; Cervantes Villegas 2012). The Bay of La Paz represents the largest body of water geographically within the Gulf of California, a situation that confers its particular oceanographic conditions for the specific concentration of photosynthetic pigments that differentiate it from the rest of the Gulf of California (PNZMAES Decree published in the DOF on May 10, 2007). The island complex is formed by two major islands, to the north La Partida Island with an area of 18.1325 km^2 and to the south Espiritu Santo Island with an area of 83,084 km^2, the latter island being the largest and providing the name for the archipelago decreed for conservation. Three islets are located off the western coast of Espiritu Santo Island, La Ballena with an area of 0.396 km^2, El Gallo with 0.057 km^2, and La Gallina with 0.019 km^2, as well as four rocky promontories: an islet with 0.046 km^2 and three others that lack official name with a total area of 0.017 km^2. Together, including the extension of the island complex covers an area of approximately 101.7515 km^2 (CONANP 2000) (Fig. 22.1).

In the central part of Espiritu Santo Island, the emerged land reaches a height of 600 m above sea level. The eastern coast of the major islands is steep and only has one extensive beach called La Bonanza in the south. The western coast of these islands is intersected by small bays, inlets, and coves with sandy beaches (CONANP 2000).

In addition to the terrestrial PNA, the importance of PNZMAES stands out. Its zoning is based on the provisions of Articles 47 Bis and 47 Bis 1 of the LGEEPA. Based on its biological, physical, and socioeconomic characteristics as a national park which includes its area of influence, this study outlines its current and potential conservation status. According to the decree assigning the area as a national marine park of the archipelago of Espiritu Santo, it is composed of two general polygons, within which are located three core zones, with their respective buffer zone (CONANP 2014).

Fig. 22.1 Location of Espiritu Santo Island Complex (known in Spanish as, CIES) (Source: Elaborated by Elizabeth Olmos-Martínez)

22.3 Materials and Methods

The methodology is adapted from the Manual of Territorial Ecological Ordinance (OET) suggested by the Secretariat of Environment and Natural Resources (SEMARNAT) (2006), which is a set of procedures for the formulation, expedition, execution, evaluation, and modification of ecological planning programs. This is a document that contains the objectives, priorities, and actions that regulate or induce the use of the soil and the productive activities of a region (SEMARNAT 2006). The OET process consists of five sequential phases: descriptive or characterization phase, diagnostic phase, prospecting or forecast phase, ecological ordering model, and instrumentation phase. For the present work, the first two phases are addressed.

1. Identification of sectors: The study area was divided into three main subsystems, according to the main activities carried out in CIES and PNZMAES, which are fishing, tourism, and conservation sectors.
2. Characterization: It consisted in the compilation, integration, and analysis of existing databases and information provided by various governmental bodies, considering the sectors selected in the CIES and its adjacent marine area.
3. Diagnosis and identification of environmental impact as a result of socioeconomic activities: The fishing, tourism, and conservation activities carried out in the study area were identified and quantified, and finally it was determined which areas have greater environmental pressure by number of activities.
4. For the development of the present study, a line of 2 km in distance perpendicular to the coast line of the island was considered. This measure was taken from the distance resulting from the tip of Isla La Ballena, which is the largest of the island's islets of the coastline of Isla Espiritu Santo.

In 2014, in order to characterize and diagnose environmental impacts, 65 surveys were applied that included stakeholders of the three main sectors (tourism, fishing, and conservation).The goal was to identify the interests of each sector and to define the environmental attributes needed to meet the interests of its stakeholders. The survey includes qualitative and quantitative variables. A different survey was applied to stakeholders of each sector.

For the identification of the environmental impact, as a result of socioeconomic activities, the methodology applied was based on a cause-effect matrix analysis (SEMARNAT 2006), modified and adapted to the interaction conditions between the activities of these processes and environmental factors, allowing for the identification of the impacts of the activities carried out on the environment. The basis of the system is a matrix in which the entries are grouped in columns containing the anthropogenic activities that can alter the environment and the entries grouped in rows are the characteristics of the environment (or environmental factors) that can be altered. With the entries in rows and columns, the existing relationships are defined. All aspects included in the socioeconomic activities carried out in the area (fishing, tourism, and conservation), as well as all environmental factors related to these, are considered.

For the identification and evaluation of the pressure on the study area, marine and terrestrial zones were separated for the analysis. This aids in identifying how many socioeconomic activities are carried out in each area and to determine which of these have a greater impact in terms of number of activities. With this date a pressure-impact gradient according by zone can be assigned according to areas with the highest (greater number of activities) and lowest (fewer activities) environmental impact-pressure.

22.4 Results and Discussion

22.4.1 Characterization

22.4.1.1 Economic Activities

The main economic activities in Espiritu Santo are oriented toward tourism of nature, as well as artisanal and sports fishing. These productive activities whether tourism or fishing require that the quality of the ecological environment be conserved and not be impacted to a level where it is no longer sustainable. The relationship between the natural attributes of the site and the maintenance of productive activities can be expressed in terms of the concept of environmental goods and services (Table 22.1); these services are necessary for the development of the region.

22.4.1.2 Fishing Sector

There are two types of fishing done in the Bay of La Paz: the first is industrial fishing and the second is artisanal or river fishing. Industrial fishing is characterized by capturing large volumes of species with technological equipment and processing for consumption, while the artisanal fishery is characterized by the use of smaller "panga"-type boats and the use of multiple fishing gear to capture a great diversity of species with the participation of different social groups (CONANP 2014).

PNZMAES is one of the most important fishing areas in the southern Gulf of California. In the period between 1987 and 1993, catches recorded in the vicinity of Espiritu Santo represented at least 20% of the total catch in the Bay of La Paz

Table 22.1 Environmental services in the CIES (land area) and PNZMAES (marine area)

Environmental services	Functions	Users
Refuge of species	Habitat for resting and migratory populations	Artisanal fishing, sports fishing, ecotourism, aquaculture
Scenic beauty	Provide opportunities for recreational activities	Sports fishing and ecotourism
Food production	Primary production of raw materials	Artisanal fishing, sports fishing, aquaculture
Recreation	Provide opportunities for recreational activities	Ecotourism and sports fishing
Culture	Provide opportunities for noncommercial use	Ecotourism and research
Other natural resources	Sources of biological material and unique products	Research, industry, and pharmaceutics

Adapted from CONANP (2006, 2014)

(CONANP 2006). Within the complex, eight fishing camps are currently established, two of which are on La Partida Island, the rest on the Espiritu Santo Island, Ensenada la Partida, Ensenada la Gallina, El Empachado, Punta Prieta, Ensenada de la Despensa, and Playa los Morritos. Throughout the coastal zone can also be identified as breeding sites of various species relevant to fishing (CONANP 2006).

22.4.1.2.1 Artisanal Fishing

According to CONANP (2011) information, artisanal or riparian fishing is carried out on a small scale by permit holders, cooperatives, and free fishermen, characterized by the use of small draft vessels. Weaver et al. (2007) conducted a survey of 80 fishermen who carry out fishing activities in PNZMAES, 45% of which belong to a cooperative society, while the remaining 55% are independent fishermen working with equipment from a buyer, owner, as a member of a fishing cooperative or with an individual permit. Among the various fishing gear used for catching are longlines, gillnets, casting nets, hooks, and harpoons. In PNZMAES more than 50 species are captured throughout the year, with the most important being huachinango (*Lutjanus peru*), mulatto snapper (*Hoplopagrus guentherii*), pierna (*Caulolatilus princeps*), jurel (*Seriola lalandi*), estacuda (*Epinephelus niphobles*), baqueta (*Epinephelus acanthistius*), cabrilla sardinera (*Mycteroperca rosácea*), perico (*Scarus perrico*, *Scarus rubroviolaceus*, *Scarus ghobban*, *Scarus compressus*, *Nicholsina denticulata*), cochito (*Balistes polylepis*), bacoco (*Haemulon sexfasciatum*), sierra (*Scomberomorus sierra*), mojarra (*Calamus brachysomus*), lisa (*Mugil* sp.) and curvina (*Cynoscion xanthulus*), palometa (*Trachinotus paitensis*), pulpo (*Octopus bimaculatus*), almeja chocolata (*Megapitaria squalida*), almeja roja (*Megapitaria aurantiaca*), mantaraya (*Dasyatis brevis*, *Urolophus halleri*, *Myliobatis califórnica*, *Gymnura marmorata*), and tiburones martillo (*Sphyrna lewini*, *Sphyrna zygaena*, *Sphyrna mokarran*, *Sphyrna tiburo*) (CONANP 2000, 2014).

According to the questionnaires applied for the present investigation, it was found that the fishermen expressed that artisanal fishing represents a source of employment for a large number of people and is a source of food resources for the population; generally the product is sold fresh or salted, in fillet or whole in the local markets. This fishing activity is, in addition to tourism, the most important economic activity carried out in PNZMAES.

22.4.1.2.2 Sports Fishing

Sports fishing, unlike riparian fishing, has been less studied and characterized, according to studies carried out by the Interdisciplinary Center of Marine Sciences (CICIMAR) and published in the CIES management program (CONANP 2000). There are records of the existence of several providers of sports fishing services in the city of La Paz that use between 25 and 30 boats, which are organized in more than 4 cooperatives and 2 companies, the number of inhabitants of the city of La Paz that use private boats to fish is unknown, but the fishing activity is on a small scale and is mainly for sport and is carried out during the weekends and holiday season, where the main species of fish captured are the tuna (*Thunnus alalunga*, *Thunnus albacares*, *Euthynnus lineatus*, *Katsuwonus pelamis*, striped bonito), gold (*Coryphaena hippurus*), sailfish (*Istiophorus platypterus*), yellowtail (*Seriola lalandi*), strong fish (*Seriola rivoliana*), roosterfish *(Nematistius pectoralis*), wavelet sardine (*Mycteroperca rosacea*), smooth snapper (*Lutjanus aratus*), snapper (*Lutjanus novemfasciatus*), snapper mulatto (*Hoplopagrus guentherii*), wahoo (*Acanthocybium solanderi*), and jacks (*Caranx hippos*) (CONANP 2011, 2014).

22.4.1.3 Tourism Sector

According to Ibáñez (2011), tourism is a key activity for the development and generation of jobs since Mexico is in the tenth place in terms of reception of tourists worldwide, a position that according to the expectations of the World Tourism Organization (WTO) will improve in 2020, a year that is expected to receive 48.9 million tourists, placing it in an eighth position.

On the other hand, CONANP (2011) has reported that there is a notable increase in tourism-recreational activities in the PNAs. The increase in visits, as the interest in managing it properly, is a phenomenon of great importance in Mexico. Studies by the Tourism Secretariat (SECTUR) have found that the PNAs are the favorite destinations to develop ecotourism and adventure tourism activities, and these have been seen as one more opportunity for development in Mexico.

In this sense, visitor growth brings both threats and opportunities for the conservation of PNAs, as tourism can have negative impacts on natural environment and social fabric due to its economic activities. Negative environmental impacts caused by tourism projects can be caused by either unregulated or even planned visitation but also in turn can generate income for the conservation and for the local communities in and around the PNA; the consequences depend on the type of tourist carried out in the PNA (CONANP 2011).

Because Espiritu Santo is the most important site for ecotourism activities in the Bay of La Paz (CONANP 2006; Cervantes Villegas 2012), maintaining the natural values that support it is strategic for the region. The scenic beauty of the islands, accentuated by the underwater richness and temperate waters of the bay, makes the area ideal for ecotourism or nature-oriented tourism.

CIES is known worldwide for its natural scenic beauty, high productivity, and endemic species, as well as for its ecological importance as a nesting and reproductive area for birds and marine mammals. It also has beaches for a variety of activities, as well as natural areas of great beauty in terms of flora and fauna (CONANP 2000, 2011, 2006). Therefore, tourism activities fall within what is considered as adventure and/or nature-oriented tourism. The tourist attractions in the terrestrial part include camping, excursions, hiking, photography, filming, recreational activities on the beach, as well as sight-seeing of flora and fauna. Of the tourist activities carried out in the marine area are swimming, scuba diving, kayaking, and boat mooring (CONANP 2000; Cervantes Villegas 2012).

For the period 2009–2010, the CIES Directorate registered a total of 54 tourist companies and granted 265 authorizations to companies providing tourism services that operate both in the park and in APFFIGC in BCS (CONANP 2011). Most of the companies carry out their activities throughout the year, and some of them only carry out their operations from October to May (CONANP 2011).

Of the 42 recreational use areas on the zoning map of the management program, there are 34 beach areas where activities such as beach outings and/or camping are most commonly carried out. Tourist camps are mainly located on the beaches on the western side of the Espiritu Santo and La Partida except for the sites prohibited in the CIES management program, Los Islotillos, Ensenada Grande, and La Ballena beach (CONANP 2000, 2006; Cervantes Villegas 2012; Olmos-Martínez et al. 2015).

Hiking is another of the tourist activities that is carried out on nine trails; five of them are located on La Partida Island and the remaining four on Espiritu Santo Island. Of these, two (Cascada Seca and La Salinita) are in the protection zone of the PNA; thus they have a type of supervised use. Sight-seeing of flora and fauna, filming, and photography are done during hiking of the trails and also from boats for the observation of sea lions and sight-seeing of birds in Los Islotes, as well as birds from the islets of La Ballena, La Gallina, and El Gallo islands (CONANP 2000, 2006; Cervantes Villegas 2012; Olmos-Martínez et al. 2015).

The tourist activities in the areas of CIES and PNZMAES are mainly carried out by means of rentals of "panga"-type boats; this service can be contracted directly without intermediaries from the main beaches or piers. The greatest presence of boats is of type "panga" followed by zodiacs which are the main means of transporting visitors to the island from cruise ships or yachts (CONANP 2011).

According to the surveys applied to tourism service providers, the time of the year with the highest visitor demand is closely associated with activity type. It has been observed that diving is carried out mostly from June to November, kayaking from January to May and from October to December, sailing from April to November, and boat rides and visit to beaches from April to November. In summary, tourism activities associated with the use of the marine area can be categorized into five modalities: diving, kayaking, sailing, naturalistic cruises, and day trips (Table 22.2).

According to the questionnaire applied to service providers, tourists that mostly visit the island are from the United States; the main reasons for the tourists visit are the great biological diversity of the area as well as favorable conditions for underwater activities. The main activities are the practice of snorkeling and scuba diving and swimming in the area known as the "lobera" where sea lions live year round on the islet of Los Islotes (in Spanish, sea lions are "lobos marinos"; the literal translation of "lobos" is wolves).

Table 22.2 PNZMAES tourist activities and characteristics

Activity	Characteristics
Diving	The trip to dive lasts for 1 day; the boats carry on board between 2 and 18 divers. The main place they visit is the "lobera" (a place where the sea lions live). Some tour operators have dive camps during the summer. All boats visit the beach and provide food
Kayaking	Kayaking is done at least 5 days a week, with an average of 20 groups per day and 18 people per group. The trips can include just paddling, or it can include a base camp, where tourists camp on a beach on the island and continue their activity the following day
Nature sight-seeing cruises and sailing	The average length is 8 days, the number of passengers varies from 4 to 130, and such visits may include hiking, kayaking, watching wildlife, snorkeling, and/or scuba diving
Day trips	Trips have duration of between 6 and 8 h; monitoring activities of flora and fauna can include walks on the island, as well as snorkeling or scuba diving when visiting populations of sea lions at the "lobera"

Adapted from CONANP (2006, 2014)

22.4.1.4 Conservation Sector

22.4.1.4.1 Conservation Activities

Management and conservation activities in the Gulf of California have increased in recent years, after it was ranked as the second most biodiverse marine space in the world (CONANP 2011). The management office of APFFIGC to which CIES and PNZMAES belong is responsible for developing strategies to reduce negative effects on the natural resources in the area. It includes actions aimed at the preservation, maintenance, restoration, and improvement of the natural environment, taking care of species of animals and plants that live in the specific area (CONANP 2014).

In addition, there are external and local organizations working for the conservation and sustainable development in the region. Examples of international organizations that have offices in the BCS include the World Wildlife Fund (WWF), Conservation International (CI), and The Nature Conservancy (TNC). Some national organizations are PRONATURA and the Mexican Conservation Fund (FMC, acronym in Spanish for *Fondo Mexicano para la Conservación*), but only PRONATURA and TNC are based in BCS. Of the 34 non-governmental organizations (NGOs) or civil society organizations in the state, three have stood out because of the strength of their efforts: (1) La Sociedad de Historia Niparajá, A.C., (2) Grupo Ecologista Antares (GEA) A.C., and (3) Grupo de Eecología y Conservación de Islas, A.C. Environmental NGOs with a presence in BCS have managed to unite to promote and exercise of collective pressure for the government to take protective actions. In 1995 the Gulf of California Coalition was formed to promote the ecological management of the Gulf of California, training for fishermen and tourism service providers, extension of PNA, and dissemination of guidelines to protect ecologically important areas, among other activities.

Considered as priority areas for conservation, CIES and PNZMAES have great relevance also for academic and governmental institutions that are important nationally and internationally, such as the Center for Biological Research of the Northwest (CIBNOR), the Autonomous University of BCS (UABCS), and the Interdisciplinary Center of Marine Sciences (CICIMAR-IPN). These local institutions have been key players in promoting conservation in the area. The relationship between academic institutions and state and federal governments has also supported the creation of PNAs, as well as projects for the protection of priority species and the conversion of productive activities toward sustainable schemes.

22.4.1.4.2 Zoning

CONANP (2006) proposed zoning for the PNZMAES, dividing the area into two polygons, one polygon for Espiritu Santo and another polygon for El Bajo, which in turn were divided into a core zone which is a protection subzone, represented by Los Islotes (0.85 km^2) and Punta Bonanza to Punta Lobos (2.21 km^2); a restricted subzone, represented by San Gabriel Bay (3.48 km^2); and buffer zones, which are special use subzones, represented by El Bajo (9.09 km^2), La Piedra Ahogada (on the side of the islets, 0.50 km2), Las Tijeretas (0.15 km^2), and La Ballena (0.76 km^2) (Fig. 22.1).

22.4.2 Diagnosis

The CIES being a PNA has double decrees of protection, on the one hand it is included in the islands of the APFFIGC, and more recently a decree was issued protecting the marine zone within the PNZMAES. This region is without doubt an ecologically important landscape that should be and is being destined to be protected. Its biogeographic importance is recognized not only nationally but internationally. It meets all conditions of a special area of great natural value and a place for carrying out of scientific, educational, and recreational activities compatible with its protection and preservation as a natural resource. In addition, it is an area where a large number of endemic species can be found and a great biodiversity which is adjacent to important marine life (CONANP 2011, 2014). Therefore, the evaluation and analysis of the relationships of the socioeconomic activities carried out in the marine and terrestrial zone of the complex show us the viability of these activities and the ability of the area to support them according to their physical and biological characteristics.

22.4.2.1 Identification and Description of Environmental Impact

The seas, oceans, and coastal zones constitute strategic spaces for the development of the country because they are suppliers of natural resources, goods, and environmental services and sources of flows of economic resources (Mesta and Martínez

2004); thus it is necessary to analyze crucial factors that are in game for its adequate development in benefit of the quality of life of the present and future generations. These same authors mention that an environmental conflict is understood as a complex process of interaction between two or more parties around one or more issues related to access, use, exploitation, control, deterioration, or conservation of natural resources or of the environment that are located in a determined territory. They suggest that the following issues that have recurred in this area can be mentioned regarding the diversity of disputed issues that can occur in marine-coastal areas: policies on management and administration of the PNA; access, use, and control of natural resources in the PNA; policies on the use, conservation, or management of natural resources; and limitations, prohibitions, or closures in the use and management or use of marine or coastal natural resources. Given the above the CIES and PNZMAES are not the exception; below the conflicts are identified.

22.4.2.1.1 Fishing Sector

According to CONANP records (2011, 2014), the island is uninhabited but is regularly visited by fishermen, fishing boats, tourists, and researchers. Artisanal fishermen have established semipermanent camps in 8 of the 11 inlets. The highest concentration of them is in the channel between La Partida and Espiritu Santo. On La Partida Island has been established for more than 20 years a permanent camp of coastal fishermen dedicated to the capture of species of scales with nets and line. The problem with the fishermen in the area is mainly reflected in the fishing camps, fishing gear used by fishermen, the management of their wastes, damage to flora, and the introduction of exotic species to the island's habitat (CONANP 2011, 2014).

Over time fishing in the area continues to increase; CONANP (2014) estimated that there are about 120 fishermen who use the area with different frequency levels. Some of these fishermen remain part of the week in camps on the islands Espiritu Santo and La Partida as part of their activity; most of them reside in the city of La Paz. Local fishermen, through questionnaires, expressed that the growing activity of sports fishing has generated social and economic problems related to "resource ownership," and they support the idea that there may be overexploitation of some of the species. The fishing gear most used by coastal fishermen on Espiritu Santo Island are nets, diving and snorkeling equipment, and fishing lines with hooks but no rod; also used extensively are gillnets which are used to catch several species of fish. The "chinchorro" is a casting fish net most used for fishing throughout the year.

According to the analysis, it can be seen that information is needed to determine if changes in fish production are related to fluctuations and abundance of resources. The uses of nontraditional fishing systems could be exerting new pressure on exploited populations; this with tourism development has increased coastal use that may be leading to greater pollution (Cervantes Villegas 2012).

In relation to the conflicts that exist between the fishing activity and other sectors, there is an increasing competition between sports fishing enthusiasts and commercial fishermen. The conflict involves fishing areas, as well as fishing resources. Environmental groups have been vocal in pointing out many of the wasteful or environmentally damaging practices of the fishermen, causing them to feel threatened since they depend economically on this activity. Moreover, fishermen compete with tourism service providers, especially on the coast and beaches, a situation that has displaced fishing grounds to other places. Illegal underwater aquaculture is one of the activities identified by fishermen as having the greatest impact on the environment since it is practiced outside the conditions specified in the regulation of the Fisheries Act (DOF 2004). Subaquatic nocturnal fishing offers advantages to the fisherman since many marine species are in a vulnerable state because they are at rest. In addition, many nocturnal catches do not comply with the species or sizes allowed by legislation (DOF 2004). The nocturnal subaquatic fishing zones identified by users in the marine area of the PNZMAES are El Bajo and around the CIES except the southwest zone (from the La Raza to Punta La Bonanza cove) (CONANP 2011).

There are also conflicts over the use of fishing gear harmful to the ecosystem such as an enclosing net, known in Spanish as an "encierre" type of net, which is generally carried out in shallow areas of the PNZMAES, such as reef areas. This fishing gear is considered harmful since it allows the capture of large quantities of organisms in a very short period (CONANP 2011, 2014). However, in the legal framework, the General Law on Sustainable Fisheries and Aquaculture (DOF 2018) does not make reference to the prohibition of the casting nets and/or methods of fishing called "encierre,"

Moreover, with free access to fishery resources, there has been an increase in competition between fishermen on the island, the Bay of La Paz, and foreigners, resulting in overexploitation of fishing resources, illegal fishing, difficulty in regulating fisheries in the area, and defining the actual fishing zones.

22.4.2.1.2 Tourism Sector

In La Paz Bay, most of the tourist activities are carried out in the PNZMAES where activities such as ecotourism or nature-oriented tourism are seen as a good option. Nonetheless, these activities carry environmental impacts such as disturbance of wildlife, collection of specimens and materials, and damage to coral communities by divers and anchors, as well as garbage generation (CONANP 2006, 2014). The different providers of tourism services compete strongly for the most attractive sites; these areas include Los Islotes, El Candelero, Ensenada Grande, and La Bonanza (Fig. 22.1).

Of the tourist activities that are offered when visiting the island, aquatic activities are those of greater interest, where the swimming is the most important followed by scuba diving, kayaking, and excursions either in "panga" or on yachts. The areas where there is more autonomous activity and swimming are in the islets of Los Islotes, La Ballena, El Gallo, and La Gallina. This activity is the most important for tourist activities and should be regulated especially in the crowded area of the island such as Los Islotes, as the impact caused by diving can effect important areas where rocky reefs are present, home to the flora and fauna. On the other hand, the artificial reefs called Fang Ming and LAPAS 03 located on the western coast of the island have served to increase the swimming zones and reduce the impact in more vulnerable areas of the complex (CONANP 2011, 2014).

According to the management plan of the PNZMAES (CONANP 2006), it is considered that for kayaking the impact is insignificant because in spite of the increase of this activity this has occurred in an organized way on the part of the service providers and routes have been established, as well as being a low-scale impact activity.

The use of boats is the second most important tourist activity that takes place in the Bay of La Paz, mainly in the PNZMAES; the most used places for the anchorage of boats are Ensenada Grande, El Cardonal, La Partida, and El Candelero. Some private boats do not use the existing marinas, so that there is no control or monitoring for them; in turn they bring with them motorized sea vehicles like zodiacs or jet skis that tourists use in the area where they anchor their boats without any restrictions (CONANP 2000; Cervantes Villegas 2012).

Recreation in the beach area represents an important impact mainly due to the generation of garbage and modification of the landscape. According to CONANP (2000, 2014), there is evidence that the most visited beaches in CIES showed changes in native vegetation and an increasingly obvious presence of aggressive weeds, as well as the absence of fragile species and even the elimination of typical forms of beaches and dunes. However, during the years 1997–2007, there was a notable recovery in camp sites mainly on La Partida Island, due to the conservation strategies related to environmental education for visitors and providers of tourist services on the authorized sites for camping and the removal of latrines installed by fishermen. On the other hand, the mangrove area near beaches has been affected by tourism due to the indiscriminate logging for use of firewood and even in order to decrease the number of mosquitoes (CONANP 2011, 2014).

According to CONANP (2011, 2014), there are some service providers in the area who are not registered and who operate without the required permits. These include some commercial or private fishermen who, despite not being registered as providers of tourist services, transport tourists to fish or visit the area. There is also the presence of private yacht-type boats, which apparently do not carry out commercial activities, but which actually provide transportation services and visits to the CIES and have no control over these cases. It should be mentioned that the office of the management of the APFFIGC, to which PNZMAES and CIES belong, performs monitoring activities by park rangers; despite this effort, the size of the PNA is so large that it complicates surveillance and care of the area.

22.4.2.1.3 Conservation

The APFFIGC and the management of the marine area of the PNZMAES are responsible for developing strategies to reduce the effects of the misuse of natural resources in the area, including actions for the preservation, maintenance, restoration, and improvement of the natural environment and the animal and plant species that inhabit a specific area (CONANP 2006, 2014).

One of the main impacts produced by human activities by tourists or fishermen is the introduction of some exotic species. According to the Conservation Group of the A.C. Islands, several decades ago, goats (*Capra hircus*) and feral cats (*Felis catus*) were introduced onto the island, which have caused ecosystem disturbances, affecting survival and abundance of both native and endemic plant communities and fauna. Goats directly damage native and endemic vegetation and are also a major competitor for the same type of food as smaller mammals such as the endemic black hare (*Lepus insularis*). Cats catch juveniles and adults of wild species, especially birds still in the nest, small rodents, and native reptiles (CONANP 2011, 2014). This situation may lead, as has occurred on many other islands, to the extinction of native species (e.g., Nogales et al. 2013).

In contrast, there is often conflict between this conservation sector and the tourism and fisheries sectors, because conservation-focused proposals seek long-term sustainable results, while the rest of the sectors seek benefits over shorter periods affecting species of flora and fauna of the area. The level of human activity in CIES and PNZMAES is one of the highest in the Gulf of California; this has resulted in a decrease in the conservation of the area. According to CONANP (2006, 2014), in order to guarantee the protection of the two PNAs and ensure sustainability in the use of their natural resources, they refer to establishing mechanisms for control and management of human uses within them.

22.4.2.2 Analysis of Pressure Due to Anthropogenic Activities

According to the surveys, it was found that the areas with the greatest pressure from socioeconomic activities are those closest to the coastline. There is also a trend toward a greater number of activities in areas closer to the city of La Paz, which is the southern part of the island. The main activities carried out in these areas with greater environmental pressure are activities associated with tourism such as snorkeling, swimming, boat anchorage, and sight-seeing excursions, including fishing activities such as those that use fishing gear that involve casting nets such as the “chinchorro” (as it is known in Spanish). It should be noted that two of the core zones established in the zoning of the PNZMAES management program, Bahía San Gabriel and Punta La Bonanza, are among the areas with the highest environmental pressure.

In Punta La Bonanza, fishing activities are carried out with the “chinchorro” in fishermen’s area. These zones are considered as a restricted subzone as defined by CONANP, activities that are not permitted, citing from their rules: “commercial diving, fishing in all its modalities and navigation by means of small recreational and sports boats.” However, they exist.

According to the surveys, the area with the greatest number of activities (greatest pressure) is La Partida Island, due to the fact that three activities are carried out here, camping by either tourists or fishermen, fishing, as well as sight-seeing excursions or hiking, and most of these activities are carried out in the coastal zone. Most of the beaches and mangrove areas in the entire study area are under average pressure, with two different activities: one is tourist or fishing camps and the other is sight-seeing excursions or hiking.

22.5 Conclusion

The Espiritu Santo Island Complex and its adjacent marine area are increasingly important for its tourist attractions and the beauty of its natural landscapes, both terrestrial and marine. Due to its proximity to the city of La Paz, there is easy access to this PNA, mainly by national and international tourists. According to the perception of the providers of tourist services and fishermen, the state of conservation of the two PNA is good; however, there is increasing environmental impact-pressure in the area.

The most visited areas receive greater negative environmental impact-pressure by the tourism, and fishing sectors in CIES and PNZMAES are those closest to the coastline and the Federal Maritime Zone (DOF 2016). The intra-sectoral conflicts between fishermen and tourism service providers have increased due to the competition for use of some areas of the complex, mainly the coastal zones located in the southern part of La Partida Island.

The sector with stakeholders causing the greatest environmental impact-pressure on the complex is tourism because it is a growing activity within the PNA, despite the fact that this activity is focused on ecotourism and adventure tourism. The growth of tourism is causing problems with the fishing sector, and the use of some areas has generated greater pollution, disturbance of flora and fauna, and introduction of exotic species.

Finally, it is important to note that the PNZMAES management program was enacted in 2014 and did not include provisions stipulating public use. This is of great relevance because this is necessary in order to indicate the location and intensity of each of the anthropogenic activities that can be carried out in this PNA. The PNZMAES public use provisions prior to becoming law, vis à vis a decree in the Official Journal of the Federation (in Spanish known as the "Diario Oficial de la Federación"), is expected to be available for public scrutiny sometime in 2018.

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Chapter 23
Functional Diversity in Plants: Implications for Conservation Issues of the Mexican Biodiversity

Clara Tinoco-Ojanguren, José L. Andrade, Oscar Briones, and Alejandro E. Castellanos

Abstract In this chapter, we explore the functional diversity concept and its importance in several ecological issues, especially maintenance of ecosystem services and conservation. We consider that Mexico's species megadiversity should be reflected into a high functional diversity. However, our knowledge on this issue is still limited. Interest in the functional diversity approach has just increased in Mexico. Despite that, since the 1970s, ecophysiological research in Mexican ecosystems has had important pioneer contributions to our knowledge on functional traits in plants and its ecological importance. In this chapter, we review some case studies describing our knowledge of plant physiological diversity in different ecosystems, as examples of the high functional diversity in Mexico. Unfortunately anthropogenic disturbance is increasingly affecting species biodiversity, in particular the more vulnerable species and ecosystems. Increasing research on the functional traits of Mexican ecosystems will provide important information about species function at the ecosystem level and species vulnerability in the context of human disturbance and/or climatic change. Studies focused in functional diversity as an important component of biodiversity will provide us a solid base for planning on conservation decisions, restoration programs, and maintenance of ecosystem services.

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23.1 Functional Diversity: Concept and Importance

Biodiversity is a multidimensional concept defining the variability of living beings, their functions and ecological complexes. It includes four components: species diversity, genetic diversity, ecological diversity, and functional or physiological diversity. Until recently functional diversity (FD) has been considered an important component of biodiversity. Diaz et al. (2007) define functional diversity as the type, range, and relative abundance of functional traits in a community. Functional traits are morphological, physiological, and phenological traits of individuals that influence growth, reproduction, and survivorship and therefore have an effect on fitness (Violle et al. 2007; Orozco-Segovia and Sanchez-Coronado 2009). Knowledge on functional traits is important to understand the mechanistic basis of species distribution, their response to environmental changes, their biotic interactions, and their role in ecosystem processes. For example, the relative abundance and diversity of species attributes in response to environmental gradients, biogeographic regions, or human disturbance, such as cattle grazing, change the functional diversity of ecosystems (Diaz et al. 2003, 2007). At a higher scale (communities), FD is the key to define the mechanisms that link biodiversity and ecosystems function (Diaz 2001 for a review; Cadotte et al. 2011).

As a growing and complex research area, there is not a unique methodology to measure FD. Most knowledge on FD has been generated at the individual and population levels since the 1970s, when technological advances allowed the possibility for ecophysiological studies. From these studies, common and meaningful traits have been collected and analyzed. To date, there are standardized protocols to measure some functional traits that are frequently measured in ecophysiological studies (Cornelisen et al. 2003). However, the selection of the system and meaningful traits to be measured depend on the study question; it is also important to include several traits to decrease the probability of species redundancy and to measure quantitative traits to capture interspecific variability (Orlandi Laureto et al. 2015). Estimations of functional diversity at more complex levels (communities) is not an easy task; therefore, indexes and models have been proposed as an approach to calculate FD (Carmona et al. 2018; Pakeman 2011).

Mexico is one of the megadiverse countries of the world; it harbors 12% of the word biodiversity, despite being a relatively small country, with 1.4% of the planet land surface. Its biological diversity is associated with the following factors: high variety of climates, complex geological history, topographic heterogeneity, and a geographical location in a wide range of latitude (14° 32′27″–32° 43′ 06″ N), resulting in a mosaic of environmental conditions. Environmental heterogeneity has led to a great variety of habitats where a high number of organisms have evolved and coexist. Furthermore, Mexico is the site of confluence of the Nearctic and Neotropical biogeographic regions, where boreal and tropical organisms converge, increasing biodiversity of species and ecosystems. Under this scenario, it is not hard to think that Mexican biodiversity is associated with a high functional diversity that might evolve in response to this highly heterogeneous environment.

Although we require more research to be focused on functional diversity to build a good scientific basis to preserve Mexico's biodiversity, conservation measurements should be a priority. In this chapter, we include some case studies describing our knowledge on plant physiological diversity for different ecosystems, as a sample of the high functional diversity in Mexico.

23.2 Functional Diversity in Seasonally Dry Forest: Plants with Crassulacean Acid Metabolism

23.2.1 Plants with Crassulacean Acid Metabolism in Seasonally Dry Forests

Crassulacean acid metabolism (CAM) is an adaptation for some plants to concentrate atmospheric carbon dioxide (CO_2) within their cells (Winter and Smith 1996; Lüttge 2004; Andrade et al. 2007). CAM is common in plants living in environments with long periods without water but also exists in aquatic plants that inhabit places where CO_2 becomes scarce during the day (Keeley and Rundel 2003). Nonaquatic CAM species assimilate CO_2 when air temperature is lower and relative humidity is higher, which is generally at night; this allows less water loss by transpiration and permits high water use efficiency. CAM plants have greater water use efficiency than C_3 and C_4 plants under similar conditions; therefore, they are distinctive of arid and semiarid regions and of forest canopies (Drennan and Nobel 2000; Winter et al. 2005; Andrade et al. 2009). In Mexico, CAM plants are emblematic, revealed in many cultural aspects, and they have even gone beyond borders: *Opuntia* spp. are the most extensively cultivated CAM crop worldwide, exceeding that of the better known pineapple (Nobel 2002; de la Barrera and Andrade 2005).

Mexican CAM plants inhabit in virtually all terrestrial ecosystems below 2000 m asl (Körner et al. 1991; Vargas-Soto et al. 2009), but the great aridity of the Mexican territory significantly favors them. In fact, Mexico is the center of origin and diversification of cacti and other CAM species, and, because most of these species are endemic, they are particularly vulnerable to changes in land use. In tropical areas, CAM species are terrestrial in short-statured communities such as dunes and dry deciduous forests and predominantly epiphytes or hemiepiphytes in taller forests (Ricalde et al. 2010; Valdez-Hernández et al. 2015). In fact, epiphytic CAM species probably also outnumber terrestrial CAM species in Mexico (Andrade et al. 2007; Silvera and Lasso 2016; Zotz 2016). In seasonally dry forests, where dry season can last several weeks, CAM species comprise important functional groups, which can be source of water and food for animals during drought; this is because they have leaves or stems structurally transformed to store or trap water (Martínez-Ramos 2008).

At a global scale, tropical seasonally dry forests are the less understood and represent one of the most threatened ecosystems (Miles et al. 2006). In Mexico, they are also the less protected even with their floristic richness and endemism (Trejo and Dirzo 2002; Dick and Wright 2005). This type of vegetation is characterized, depending of the precipitation, by having 25–100% of the composing tree species losing their leaves during the dry season (Miranda and Hernández 1963), when light intensity and air temperatures can change dramatically (Graham and Andrade 2004). Dry deciduous forests of Mexico are rich in CAM species, which are from diverse families and at high densities, and in some forests, some terrestrial species can even be ecologically the most important species (Ricalde et al. 2010). Moreover, abundance of nitrogen fixer legumes in some dry forests can induce growth in accompanying terrestrial CAM plants since epiphytic CAM species receive most of their nitrogen from atmospheric sources (Santiago et al. 2017). Additionally, relative capacitance (the capacity of the tissues to maintain their water potentials when the water content decreases) is higher for terrestrial CAM species than for CAM epiphytes (Andrade et al. 2009).

23.2.2 Terrestrial CAM Species

Terrestrial CAM plants have succulent stems or leaves that store water. Also, rosette forms of species from several CAM families have a role to capture rainfall and even fog (Martorell and Ezcurra 2002). So, these specialized storage tissues can transport water to maintain turgor in the photosynthetic tissues during drought (Goldstein et al. 1991; Lüttge 2004; Andrade et al. 2009). In the rainy season, CAM photosynthesis can enhance; many studies reveal that the greatest tissue acid accumulation (a proxy for CO_2 uptake) of terrestrial CAM plants in seasonally dry forests takes place during the rainy season (Andrade et al. 2006; Cervera et al. 2007; Vargas-Soto et al. 2009; González-Salvatierra et al. 2010; Ricalde et al. 2010), with lower air temperatures and vapor pressure deficits than during the rest of the year.

Seedlings of terrestrial CAM plants cannot have enough water in their tissues to endure long dry seasons but have higher survival probabilities under the canopy of nurse plants (Esparza-Olguín et al. 2002; Flores et al. 2004; Cervera et al. 2006). Although this phenomenon has been widely documented in different sites (Valiente-Banuet and Ezcurra 1991; Godínez-Álvarez et al. 1999, 2003), few studies have measured microenvironmental and physiological differences for seedlings and adults, which provide information for conservation purposes. For instance, seedlings of the rare cactus *Mammillaria gaumeri* do not survive under more than 20% of ambient light; however, adults increase growth at exposed locations (40–80% of ambient light), indicating that some disturbances can be beneficial for adults of this species (Cervera et al. 2006, 2007).

The enzyme that fixes CO_2 at night in CAM plants, phosphoenolpyruvate carboxylase (PEPc), does not discriminate against $^{13}CO_2$, whereas ribulose bisphosphate carboxylase (RuBisCO), which fixes carbon during the day, favors ^{12}C fixation.

Then, studies on carbon isotopic composition ($\delta^{13}C$) provide information on the proportion of CO_2 fixed during the night or day (Griffiths 1992). CAM plants with CO_2 uptake exclusively at night, by PEPc, would have $\delta^{13}C$ values around −11 °/oo (close to atmospheric values), whereas if all CO_2 is fixed by RuBisCO the values of $\delta^{13}C$ would be about −27 °/oo (O'Leary 1988). In northern Yucatan, tissue $\delta^{13}C$ values for terrestrial CAM plants of the coastal dunes are 2 °/oo higher than CAM plants from the tropical dry deciduous forests (Ricalde et al. 2010), which indicates greater CO_2 fixation through the CAM pathway in sites with less water.

During the dry season, the lack of water and high temperatures can affect growth and reproduction of CAM species; high temperatures increase respiratory rates, and plant tissues must invest photosynthetic products to repair the photosynthetic apparatus from photoinhibitory damage, which leads to lower investment against pathogens and predators (Cervantes et al. 2005; Andrade et al. 2009). Optimal diurnal/nocturnal temperature for CO_2 uptake of some species in seasonal dry forests is 30/20 °C (Nobel 1985; Nobel and de la Barrera 2002). Temperatures above or below this optimal, especially the nocturnal ones, reduce growth in CAM plants (Andrade et al. 2007).

A specific group of terrestrial CAM plants belongs to the genus *Clusia*, with species with C_3, C_3/CAM, and CAM pathways (Winter and Smith 1996; Winter et al. 2005; Lüttge 2006). In Mexico, there is a preponderance of C_3/CAM *Clusia* species, but in seasonally dry forests, all species are CAM (Vargas-Soto et al. 2009).

23.2.3 Epiphytic CAM

Vascular epiphytes inhabit a very dynamic microenvironment, where light, nutrients, and water can change drastically in time and space (Benzing 1990; Lüttge 2008; Zotz 2016). In seasonal dry forests, epiphytes are prevalently CAM, but they have also evolved several morphophysiological adaptations such as succulence, reduced stomatal size and density, and specialized root, leaf, and stem structures (Winter et al. 2005; Andrade et al. 2009; Petter et al. 2015; Zotz 2016). Epiphytes from seasonally dry forests of Mexico also represent a main group of interest for physiological studies even though they are not as diverse, abundant, or important in biomass as in wet forests.

Vertical distribution of epiphytes in the dry forests is more related to light than to host tree species; most species are concentrated in the middle part of the host trees, mainly on the main stem or in branches near the main stem (Cervantes et al. 2005; Reyes-García et al. 2008; Cach-Pérez et al. 2013; Chilpa-Galván et al. 2013; de la Rosa-Manzano et al. 2014a). Some studies suggest that species distributed within the lower canopy avoid excess radiation (Griffiths and Maxwell 1999; Reyes-García and Griffiths 2009; Reyes-García et al. 2012). Indeed, species within the upper canopy can be more tolerant to high light but paradoxically may also be able to obtain more water (rainfall, fog, and dew) than species in the lower canopy (Andrade 2003;

Graham and Andrade 2004; Reyes-García et al. 2012). However, although microclimatic conditions can contribute to the vertical distribution of CAM epiphytes in tropical dry forests, factors such as seed dispersers, bark traits, competition, facilitation, and other variables need further investigation to determine their role on such distribution (Benzing 1990; Chilpa-Galván et al. 2017).

Additionally, epiphytes with CAM have a morphology and physiology modified to tolerate water scarcity and high light incidence (Benzing 1990; Zotz and Hietz 2001). For instance, epiphytic bromeliads may store water in succulent tissues or in water-storing tanks and may absorb water and nutrients through modified leaf trichomes (Benzing 1990; Reyes-García et al. 2012). Epiphytic orchids have water storage capacity in their stems or pseudobulbs and on specialized roots with a highly absorptive velamen (de la Rosa et al. 2014b). Also, epiphytic bromeliad densities are inversely related to vapor pressure deficit (VPD, Cach-Pérez et al. 2013). Low values of VPD diminish the rate of water loss and allow a high probability for deposition of dew (Chilpa-Galván et al. 2013; de la Rosa et al. 2014b). In the north of Yucatan, water table can be very shallow, and, in locations where trees can reach it, low-VPD canopy islands emerge with high epiphyte densities (Chilpa-Galván et al. 2013).

In seasonally dry forests, the open canopy of trees and pinnate leaves offer poor protection to epiphytes against high incident light. Furthermore, trees also lose their leaves during the dry season with a consequent increase in photooxidative stress in epiphytic leaves, which carries a decrease in the quantum efficiency of photosystem II and a decline in CO_2 assimilation (Valdez-Hernández et al. 2015). However, it has been reported that epiphytes with CAM avoid the production of the harmful reactive oxygen species, reducing photoinhibition and oxidative stress (Niewiadomska and Borland 2008). CAM is advantageous to cope with drought because it creates high CO_2 concentrations in the cytosol and chloroplasts, favoring Rubisco's carboxylation activity over its oxygenase activity, maintaining electron transport, and preventing damage to photosystems (Niewiadomska and Borland 2008). Moreover, epiphytic bromeliads increased the production of antioxidant compounds and flavonoids as a response to high light and other stressful conditions (Saito and Harborne 1983; González-Salvatierra et al. 2010). Also, leaf trichomes on bromeliads are highly reflective and could have an important role in photoprotection of leaves exposed to direct sunlight (Pierce 2007). For instance, individuals of tank species on deciduous hosts in short-statured dry forests have larger trichomes compared to species on host in taller less drier forests (Cach-Pérez et al. 2016).

Epiphytic orchids have also diverse mechanisms to remove or avoid excess light and heat, including a reduction of leaf area to increase heat flux by conduction and convection, carotenoid production, and photosystem II heat dissipation of absorbed energy (Vaz et al. 2004; Adams et al. 2008; de la Rosa-Manzano et al. 2014b, 2015). Not surprisingly, epiphytic orchids produce more carotenoids (such as lutein and neoxanthin) during the dry season than during the wet and early dry seasons in tropical dry forests; also, the concentrations of these pigment are higher in leaves of orchids from the deciduous forest than those from the semi-deciduous forest (de la Rosa-Manzano et al. 2015). These differences in carotenoid compositions between epiphytic plants growing at high vs. low light are similar to the general plant responses reported by Demmig-Adams and Adams (1992).

Additionally, orchid leaves from a dry deciduous forest have higher zeaxanthin retention and lower values of maximum quantum efficiency of photosystem II (F_v/F_m) during the dry season than orchids from a semi-deciduous forest (de la Rosa-Manzano et al. 2015). These changes are related to high incident light and the prolonged dry period that occur in the tropical dry deciduous forests, when practically all trees shed their leaves. Moreover, in contrast to terrestrial CAM species, for epiphytes CAM photosynthesis enhances during the early dry season, particularly in the dry deciduous forest, when lower air temperatures, light, and minimal VPD occur than during the rest of the year (de la Rosa-Manzano et al. 2014b, 2015); indeed, dew and fog have higher deposition rates during this season (Andrade 2003; Reyes- García et al. 2012), which are conditions that favored a higher stomatal conductance to increase CO_2 uptake.

Epiphytes have a distinct isotopic composition of nitrogen (^{15}N) values in a tropical dry deciduous forest because they must obtain most of their N from the atmospheric sources than for decaying organic matter (Santiago et al. 2017). Low ^{15}N values in epiphytes have been reported for other forests and for organic N in precipitation of non-polluted areas (Stewart et al. 1995; Cornell et al. 1995; Hietz et al. 1999).

It would be important to study multiple stress factors for CAM epiphytes in combination to measure plasticity and predict plant responses to future climate change (Prasch and Sonnewald 2015; de la Rosa-Manzano et al. 2017), vital information for conservation, and restoration programs. Since the future of epiphytes is uncertain in this changing world (Zotz 2016), research that highlights the potential of these species as ornamentals or biological indicators is extremely important.

23.3 Functional Diversity in Drylands: Environmental Tolerance and Species Adaptation in Mexican Drylands

Diversity and abundance of response traits change in plant communities in response to historical, biogeographical, and environmental local effects and more recently to man-made disturbances and global change. Functional diversity in plant communities of dryland ecosystems reflects the different adaptive responses to water limitations. Low and infrequent precipitation amounts and rainfall events or pulses with extreme high temperatures are the main selective factors for the different functional groups in dryland ecosystems (Noy-Meir 1973; Schwinning and Ehleringer 2001; Reynolds et al. 2004). In Mexican drylands, plant functional groups are numerous considering the different adaptive responses of leaves, stems, and roots to selective environmental and biological factors (Shreve 1942; Miranda and Hernández-Xolocotzi 1963). Response traits have an effect and influence ecosystem function as species ecophysiological traits are affected by the environment. For example, functional diversity in Mexican dryland species correlate with morpho-structural proxies of drought-enduring mechanisms such as leaf and leaflet size and life span, stem height and numbers, and root and water storage characteristics (Miranda and Hernández-Xolocotzi 1963) that are a consequence of the diverse adaptive ecophysiological responses, such as temperature and drought tolerances, photosynthetic capability, and water use efficiency (Flexas et al. 2002; Castellanos et al. 2010; Ryel et al. 2010; Medrano et al. 2015).

Mexican drylands are widespread and cover about 55–60% of the country, most of which correspond to the Northern Chihuahuan and Sonoran deserts. In Northwestern Mexico in the Sonoran Desert, the Neotropical and Temperate biogeographic regions meet in the Central Region of Sonora (Rzedowski 1978; Castellanos et al. 2010) and sustain some of the largest diversity of plant functional types. An example of the functional diversity in that region is the presence of one of the most abundant vine floras in the world (Castellanos 1991; Rundel and Franklin 1991; Molina-Freaner et al. 2004), even though vine species diversity are known to decrease from the tropics to temperate regions (Gentry 1983; Ewers et al. 1991). Vine species are present in the region and their diversity increase toward the high rainfall end of a precipitation gradient. Measured for C_3 species only, mean vines species increase their water use efficiency in the driest sites, but their mean water use efficiency was lower in sites with higher annual rainfall, as measured by isotopic ^{13}C discrimination (Table 23.1). Differential leaf isotopic carbon discrimination by the photosynthetic enzyme RUBISCO (ribulose bisphosphate carboxylase-oxygenase) and stomatal control is correlated to water use efficiency and reflect the different long-term physiological mechanisms that control water loss, such as smaller diameter in xylem cells and hydraulic conductivity and stomatal regulation to minimize leaf transpiration under the region harsh environments (Castellanos 1991; Molina-Freaner and Tinoco-Ojanguren 1997; Castellanos et al. 1999; Molina-Freaner et al. 2004). As in other studies, we found larger variability in the functional diversity within site than between sites.

Drylands species have a number of other different functional strategies and attributes that allow them to adapt to the limiting water conditions of dryland

Table 23.1 Overall mean ^{13}C isotopic ratio for species in each of five sites along an aridity gradient in Sonora in Northwestern Mexico

Sites	Rainfall (mm)	∂13C	s.e.	
BK	121.8	26.74	0.09	*a*
HMO	349.3	27.51	0.12	*ab*
COL	348.9	28.32	0.19	*cd*
SFO	431.1	28.04	0.13	*bc*
SJV	524.2	28.99	0.16	*d*
Mean		28.33	0.09	

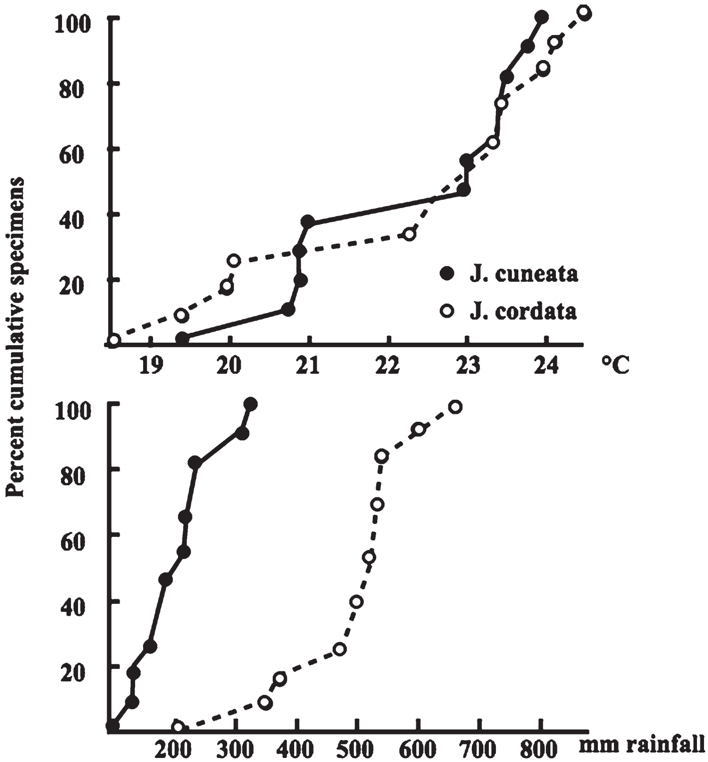

Fig. 23.1 Percent cumulative number of specimens of *Jatropha* species versus their mean annual temperature and rainfall along their known range of geographic distribution. Data were obtained with MaxEnt tool for species distribution modeling

habitats, such as the increasing niche differentiation within their biogeographic distribution range. *Jatropha* species are able to differentiate their species distribution ranges, within the arid and subtropical ecosystems in Northwestern Mexico, along both precipitation and temperature gradients (Fig. 23.1). *J. cuneata*, a species characteristic of some of the most arid regions of Mexico, has a lower and much narrower range of precipitation in their habitats. On the contrary, *J. cordata*, a characteristic species to subtropical shrublands and deciduous forests in Northwestern Mexico (INEGI 2000), has a wider range of precipitation in the habitats it is found. Both *Jatropha* species are drought evaders, and their fleshy roots and stems may store important amounts of water, such that when water is available, they sustain some of the highest leaf water potentials during the day, compared to other species in the same site (Table 23.2). Poor stomatal control of *Jatropha* leaves, however, may be responsible for their rapid leaf senescence, soon at the end of the rainfall season (Castellanos pers. obs.). *Jatropha* also characterize the contribution of species from the subtropical biogeographic regions to the large diversity and contrasting physiological responses and adaptations of plant functional types in the drylands of Mexico.

Table 23.2 Predawn water potentials for different functional-type species from the Sonoran Desert in Mexico

Species	Growth form	Predawn water potential (-MPa)	Root depth (cm)
Olneya tesota	Evergreen tree	3.85	145–180
Jatropha cordata	Succulent deciduous tree	0.72	45–60*
Mimosa laxiflora	Shrub	6.00	145
Jatropha cardiophylla	Succulent shrub	0.25	60–90*
Encelia farinosa	Perennial herb	3.10	15–50

Rooting depth assumes night equilibrium of plant and soil water potentials and with roots in Jatropha species

23.3.1 Threatens to Functional Diversity in Mexican Drylands: Global Change and Land Use Cover Change

The large contribution of Neotropical floristic elements to the functional diversity of Mexican drylands may also be the major drawback to their richness and functional diversity in the future. Given the current scenarios and the major drivers of global change, increasing atmospheric CO_2 concentration, GH gases, and land use changes and deforestation, their effects are more notorious in Mexican drylands. Global change will increase annual temperatures, decrease rainfall amount, and change their seasonality (Seager et al. 2007b, 2009). Global change will have unknown but likely differentiated effects on species niche distribution (Villaseñor and Téllez-Valdés 2004; Moghaddam-Gheshlagh et al. 2017); their abundance, composition, and diversity (Archer et al. 1995; Archer and Predick 2008); biogeochemical cycles (Delgado-Baquerizo et al. 2013; Yuan and Chen 2015); and ecosystem function (Smith et al. 1997; Pan 2000; Chapin 2003). In the Central Region of Sonora, for example, *Jatropha* species, *J. cuneata* and *J. cordata*, have easily differentiated distribution niches along a rainfall, but not a temperature gradient (Fig. 23.1). Given the proposed global change scenarios of increasing temperature and decreasing rainfall in the region (Seager et al. 2007a, b), it is expected that *J. cuneata* will expand their range of distribution, and *J. cordata* will be the most affected, decreasing their distribution and abundance in the future, as current populations are commonly found in habitats with 350 mm annual precipitation or more. It is clear that many more ecophysiological studies are needed to determine the extent and severity of local effects of global change in the different plant species in Mexican drylands.

Change in arid land use is the main driver of global change in Mexican drylands. For more than 400 years, cattle grazing has been a major activity in arid plant communities and have induced changes in species abundance and composition, reducing the most palatable and increasing the more unpalatable (McIntyre et al. 2003; Callaway et al. 2005; Díaz et al. 2007; Dorrough et al. 2007; Hanke et al. 2014). In some drylands plant communities, overgrazing was detected, probably accentuated by a period of prolonged droughts, during the 1850s (Archer et al. 1995; Buffington and Herbel 1965; Seager et al. 2007a). During the mid-1950s, introduction of exotic grasses and rotation of grazing lands increased cattle stocking level in ranches (Bravo-Peña et al. 2010; Castellanos et al. 2010; Brenner 2011). Some of the ecological and environmental consequences of those management practices are still unknown and unmeasured.

Functional diversity is reduced after exotic buffelgrass savannas are established. Bulldozing of plant communities to establish buffelgrass grasslands or savannas removes most of herbs, shrubs, and most species of trees, reducing plant diversity (Saucedo-Monarque et al. 1997; Castellanos et al. 2002). Once buffelgrass is established, there may be some reestablishment of trees and shrubs (Castellanos et al. 2010; Tinoco-Ojanguren et al. 2013), although some others may be inhibited (Morales-Romero and Molina-Freaner 2008; Morales-Romero et al. 2012). In sites were buffelgrass savannas were established, many other functional processes may be changed. We have documented changes in ecosystem productivity (Hinojo-Hinojo et al. 2016), nitrogen mineralization (Celaya-Michel and Castellanos-Villegas 2011; Celaya-Michel et al. 2015), soil carbon accumulation (Castellanos et al. 2010; Morales-Romero et al. 2015), and soil moisture distribution, recharge, and availability in the soil profile (Castellanos et al. 2016). Water availability after prolonged rainfall periods increases in the soil profile under buffelgrass canopies, because of their limited rooting depth, and can be used by the remaining deep-rooted dominant tree and shrub species. Increasing the storage and availability of water in the deeper soil profile of the savanna (Fig. 23.2) decouple rainfall season and the time of water use by the remaining species and extend the amount of time during the year in which the species remain productive (Hinojo-Hinojo et al. submitted). It is noteworthy that changes in land cover and disturbance will reduce shallow water consumption and increase infiltration and volumetric soil moisture deeper in the soil profile. Increase in deeper soil moisture in subtropical drylands decouple plant activity from rainfall periods and extend the period of photosynthetic carbon gain and ecosystem productivity of deep-rooted perennial shrubs and trees (Scott et al. 2006, 2014), when other environmental factors like below zero temperatures or cloudiness are not limiting. Some species of dominant tree species in the drylands of Mexico are known to help redistribute water from deep to shallow roots and facilitate the growth and activity of annual and herbaceous perennial plants (Hultine et al. 2003, 2004).

23.4 Ecophysiological Tolerance of Ferns in the Cloud Forest

23.4.1 The Cloud Forest

Low and often-twisted deciduous and evergreen trees and high abundance and biomass of epiphytes characterize the cloud forest (Hietz and Hietz-Seifert 1995; Crausbay and Martin 2016). Cloud forest is distributed in fragmented form

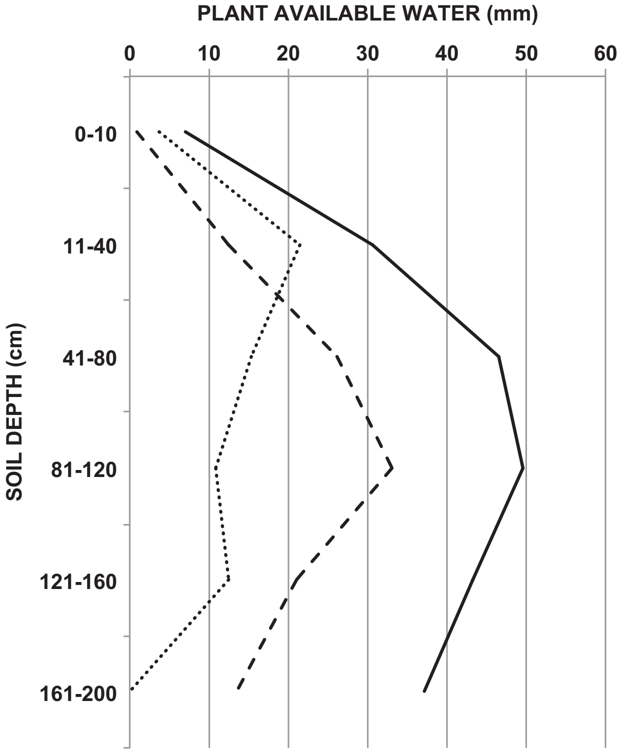

Fig. 23.2 Plant available water (mm) in the soil profile under the canopy of *Olneya tesota* (ironwood) in native (*dashed*) and disturbed (*pointed*) sites and *Cenchrus ciliaris* (buffelgrass, *solid line*) after the rainfall season (2012). Values result from the integration of 10 cm depth intervals

between 1000 and 3500 m of altitude, in rainy and cold mountains with high frequency of clouds and mist that limit the incidence of sunlight inside the forest (Lüttge 2008). Cloud forest collects large amounts of rain; however, there are periods without rain that can last several weeks and cause seedling mortality (Engelbrecht et al. 2005).

Climate changes and human disturbances have affected the distribution and decreased the extension of cloud forest (Foster 2001; Crausbay and Martin 2016). It has been predicted that the cloud forest will change to new climatic zones, but it will not move as a unit because it is composed of many species and possibly each one will respond in a particular way to the human-induced global change. However, the data commonly used to model the potential distribution of the species is made with average values of the climate, without taking into account the physiological tolerance of the plants to the physical conditions of the microhabitat, which can differ substantially from the regional climate (Foster 2001; Zotz and Bader 2009). Therefore, an important task is to know the physiological responses of plants to the environmental conditions of the ecosystems where they live.

23.4.2 Ecological Groups of the Ferns in the Cloud Forest

Light intensity is one of the most important environmental factors that influence the abundance, growth, and survival of plants in Tropical Mountain Forests (Poorter and Arets 2003; Lüttge 2008). Different light environments caused by the fall of trees and edges of the forest favors the coexistence of species with different light requirements (Chazdon et al. 1996). Shade-tolerant plants have low phenotypic plasticity in response to changes in the light environment, compared to sun-tolerant plants. Shade-tolerant plants show low photosynthetic and respiration rates and are slow growing, while light-demanding plants show higher photosynthetic and respiration rates and are fast growing (Chazdon and Smith 1996; Poorter and Arets 2003). In addition, the species are able to acclimatize physiologically to the seasonal climatic changes of the Tropical Mountain Forests (Chazdon et al. 1996). In ferns, interspecific differentiation in the response of the spore to the physical environment and tolerance to desiccation in the gametophyte has been associated with the preference of the habitat of the sporophyte (Pérez-García et al. 1982; Watkins et al. al. 2007; Testo and Watkins 2013; Riaño et al. 2015). Similarly, differences in distribution and physiological response between sporophytes of fern species that inhabit the same community support the hypothesis that the differentiation of niches promotes the coexistence of species (Hietz and Briones 1998; Arens and Sánchez-Baracaldo 1998; Durand and Goldstein 2001; Saldaña et al. 2010; Volkova et al. 2009, 2010; Bystriakova et al. 2011; Riaño and Briones 2013, 2015).

Several authors have made contributions to recognize functional groups in ferns. In the middle of the last century, the ferns of Singapore and Malaysia were divided according to the habitat where they grow in terrestrial sun, terrestrial shadows, rocks, banks of gullies, aquatic, and mountain species (Holtum 1954). The physiological behavior of terrestrial cloud forest ferns characterizes them as shade plants because they tend to show low photosynthetic and respiration rates and are slow growing (Chazdon and Smith 1996; Poorter and Arets 2003). It has been hypothesized that the tolerance of ferns to low light environments is due to the action of phytochrome PHY3 and neochrome, because both photoreceptors are sensitive to blue and red light (Kawai et al. 2003; Li et al. 2014). However, there are important differences between species of tropical terrestrial ferns in the distribution and degree of shade tolerance (Durand and Goldstein 2001; Jones et al. 2007; Bystriakova et al. 2011; Riaño and Briones 2013, but see Volkova et al. 2010). In a cloud forest where several species of ferns coexist, the arborescent fern *Alsophila firma* was abundant in gullies and humid sites, the arborescent *Cyathea divergens* and the herbaceous *Blechnum schiedeanum* occupied moderately open sites, while the arborescent *Lophosoria quadripinnata* and the herbaceous *B. appendiculatum* preferred more open sites (Riaño and Briones 2013; López-Romero et al. 2016).

With respect to humidity, epiphytic species have been grouped into poikilohydric and homohydric hygrophytes, mesophytic, and xerophytic that tolerate drought or evade it (Benzing 1990). In relation to light, the epiphytes have been categorized as exposed with total or almost total exposure to the sun, sun with growth in half shadow and shade-tolerant to deep shadow (Pittendrigh 1948; Benzing 1990). The epiphytic species in the cloud forest prefer different zones in the sporophyte. These zones are distinguished by their height, thickness, and inclination of the branches and composition of the substrate accumulated in the branches (Johansson 1974; Kelly 1985; Ter Steege and Cornelissen 1989; Hietz and Hietz-Seifert 1995; Hietz and Briones 1998; Rudolph et al. 1998). The distribution of the biomass of the epiphytic fern species in a cloud forest was unequal in the sporophyte and allowed to classify them based on their apparent luminance requirement (Hietz and Briones 1998). The deep shade-tolerant type composed of *Trichomanes bucinatum* and *Asplenium cuspidatum* showed 85–100% of the biomass confined to the base and bark of the trunks. The sun type or tolerant to medium shade formed by *Elaphoglossum glaucum*, *E. petiolatum*, *Phlebodium areolatum*, and *Polypodium puberulum* distributed 80–100% of its biomass in the upper trunk and branches thick >20 cm and medium thick >5 cm diameter. The exposure type was composed of *Pleopeltis mexicana* and *Polypodium plebeium* with 70–95% of its biomass on relatively thick branches of 5–20 cm and thin <5 cm in diameter (Hietz and Briones 1998).

23.4.3 Ecophysiological Tolerance of Ferns of the Cloud Forest

The spore, gametophyte, and sporophyte are the most important phases of the life cycle of the ferns (Sharpe and Mehltreter 2010). The spore is a haploid cell dispersed by the wind, but due to its small size (25–50 μm), it can remain in the pores of the soil and keep dormant forming a bank of spores (Pérez-García et al. 1982; Sharpe and Mehltreter 2010). The gametophyte is a laminar and tiny plant with rootlets, without vascular tissue or stomata, has little capacity to store water, and can be poikilohydric but requires water for fertilization, while the sporophyte is a conspicuous perennial plant, with vascular tissue, rhizome, roots, and leaves with stomata and sori (Farrar et al. 2008; Watkins et al. 2010). Due to these differences, the sporophyte and gametophyte can have independent environmental tolerances and optimally succeed in different habitats (Warne and Lloyd 1980). The physiological limitations of the ferns determine that many species grow under the shade of the canopy or in humid places of the cloud forest (Hietz and Briones 1998; Riaño and Briones 2013; López-Romero et al. 2016). However, ferns are physiologically competitive and have a large number of adaptive characters resistant to abiotic stress, so that they can colonize shady sites, as well as open areas and can survive in flooded and degraded lands (Hietz and Briones 2004; Hietz 2010; Mehltreter et al. 2010; Watkins et al. 2010).

23.4.3.1 Ecophysiological Tolerance of the Spore Germination

Light and water are the resources that mostly limit the germination of the fern spores, and their success in germinating has an important influence on the distribution of the species. The spores of species whose sporophytes grow in shade environments germinate better in conditions similar to the interior of the forest, such as lower temperature, low light, and high availability of water, while those that are distributed in open or exposed environments germinate in higher values of temperature, light, and water availability (Warne and Lloyd 1980; Pérez-García and Riba 1982; Riaño et al. 2015; López-Romero et al. 2016). The light promotes the germination of the spores of the ferns through a system of phytochromes. Phytochrome-dependent germination can be photoreversible with a far-red irradiation and can be photoreversible by brief irradiation with blue or UV light (Raghavan 1989). With the phytochrome system, the spore detects light in the gaps forest and the proximity to the soil surface, which allows the spores to germinate under favorable conditions for the growth of the gametophyte and sporophyte (Pérez-García et al. 2007). No spores germinated under far-red light or darkness; but germination was high under white light in four species of tropical ferns (Pérez-García et al. 2007). The temperature for the germination of fern spores ranges between 15 and 30 °C, and the optimum germination temperature of five arborescent species was 25 °C (Pérez-García and Riba 1982). *Lophosoria quadripinnata* and *Trichipteris bicrenata* had the highest tolerance to extreme temperatures in a thermal gradient of 11–35 °C, while *Trichipteris scabriuscula* had the lowest tolerance; *Nephelea mexicana* and *Cyathea fulva* had an intermediate tolerance (Pérez-García and Riba 1982). The spores of *Alsophila firma*, *Lophosoria quadripinnata*, and *Cyathea divergens* seeded at 13 °C, 21 °C, and 25 °C increased germination with the increase in temperature, but *L. quadripinnata* had higher thermal tolerance compared to *A. firma* and *C. divergens* (Salvador 2014). In six ornamental fern species, it was found that the best substrate for germination was the mixture of peat pH 6 and perlite, reaching 100% germination of *Cyathea cooperi*, *Pteris cretica*, and *P. incompleta*, but with mixture of peat pH 4 and pearlite germination decreased significantly in *Cyathea cooperi*, *C. contaminans*, and *C. tsangii*, and the lowest germination percentages of all species, including *Asplenium nidus*, were obtained in sand substrate (Barros et al. 2008). In *Dryopteris munchii*, twice as many gametophytes were obtained in spores germinated in soils derived from volcanic toba, in comparison with those obtained in chromic luvisol soil (Jaramillo and Mendoza 2004).

The differences observed in the frequency of individuals in the understory and the correspondence of the spore's physiological behavior with respect to water availability support the hypothesis that the coexistence of five sympatric species in a cloud forest occurs by differentiation in the ecological niche from early stages of the individual's development (Riaño et al. 2015; López-Romero et al. 2016). The germination of the spore of the herbaceous species *Blechnum appendiculatum* and *B. schiedeanum* and the arborescent tree ferns *Alsophila firma*, *Lophosoria quadripinnata*, and *Cyathea divergens* was controlled by exposure to light and water availability. The spores of all the species did not germinate under darkness, and the germination was smaller with far-red light, compared with white light. All species germinated at very low photon flux density (0.04 μmol m^{-2} s^{-1}) and increased germination with the amount of light received, but the saturation of germination was different between species. The decrease in available water from 0 to −0.7 MPa reduced germination in all species, and the water requirements for germination were associated with the habitat preference where sporophytes grow. The increase in canopy opening from 0.6% to 19.1% decreased the germination capacity of the three species of tree ferns, but *L. quadripinnata* was the least affected (Riaño et al. 2015).

23.4.3.2 Ecophysiological Tolerance of the Gametophyte

The gametophyte of a fern may have a broader environmental tolerance than its sporophyte and is physiologically similar to the gametophyte of a bryophyte (Ong et al. 1998; Farrar et al. 2008). The distribution of fern gametophytes depends on multiple environmental conditions and resources, and disturbance is also important (Farrar et al. 2008). In sites with low light and no disturbance in a humid forest, no gametophytes were established, while in high light sites, the density of gametophytes was increased by the removal of the litter and when the topsoil layer was removed and exposed (Watkins et al. 2007). The gametophytes of the arborescent ferns *Alsophila firma*, *Cyathea divergens*, and *Lophosoria quadripinnata* when they grew with 42% and 85% solar radiation in shade houses and with 7% and 23% of solar radiation in the understory of a cloud forest decreased the quantum yield (proportion of the light used in photosynthesis) and increased the electron transport rate of photosynthesis in treatments with higher solar radiation; however, solar radiation decreased the survival of the three species, and *L. quadripinnata* had higher survival in comparison with *A. firma* and *C. divergens* in the shade house with higher solar radiation (Salvador 2014). Gametophytes of the same three species subjected to>96% RH did not reduce the quantum yield, but it decreased strongly to 69% and 35% of relative humidity and gametophytes tolerated direct solar radiation up to 30 min (Riaño and Briones 2015). The high dependence of gametophytes from tree ferns to humid environments could explain why these species, and possibly other species with similar life histories, are restricted to humid forests (Bystriakova et al. 2011; Ramírez-Barahona et al. 2011; Riaño and Briones 2015).

In comparison with the sporophyte, there have been very few studies on the photochemistry and carbon metabolism in the gametophyte. The CO_2 assimilation rate of the gametophytes of four fern species (of the genera *Cibotium*, *Todea*, *Pyrrosia*, and *Thelypteris*) ranged between 0.03 and 0.18 μmol CO_2 g^{-1} s^{-1} (Farrar et al. 2008). Photosynthetic rate of the gametophyte could be compared with that of a young sporophyte in an epiphytic fern, obtaining values of 0.18 and 0.14 μmol CO_2 g^{-1} s^{-1}, respectively (Sakamaki and Ino 1999). The gametophyte of 15 fern species recovered their physiological functioning after dehydration, and the capacity for recovery was variable among the species (Farrar et al. 2008). The quantum yield of the gametophyte of an epiphytic fern species that grew in exposed environments recovered almost completely after 24 h of desiccation, while it decreased strongly in the same period of desiccation in another species of terrestrial fern that inhabited shaded sites (Farrar et al. 2008). The gametophytes of the tropical epiphytic ferns *Phlebodium pseudoaureum* and *Microgramma reptans* recovered the initial values of quantum yield after exposure to treatments of low relative humidity; however, the gametophytes of *Diplazium striatastrum*, a terrestrial species that grows in humid environments within the forest, were unable to recover their quantum yield values (Watkins et al. 2007). The gametophyte of *Asplenium scolopendrium* var. *americanum*, a rare species with low abundance in a Temperate Forest, could not tolerate a relative humidity <90%, in comparison with other species of the same genus and common in the same forest that presented physiological tolerance to desiccation (Testo and Watkins 2013).

These authors attributed interspecific differences in relative humidity tolerance to habitat preference among species. The gametophytes of *Asplenium trichomanes*, *A. scolopendrium*, and *Ceterach officinarum* showed similar capacity to acclimate their photosynthetic apparatus to the increase of the quantity of light modifying the content of photoprotective pigments (Fernández-Marín et al. 2012). The pigments of the gametophytes of these three species were not qualitatively different from those of the sporophytes of seven species of epiphytic ferns (Tauz et al. 2001).

23.4.3.3 Ecophysiological Tolerance of the Sporophyte

The sporophyte leaf of ferns behaves like the leaf of other vascular plants (Hietz and Briones 1998; Watkins et al. 2010). The cuticle and stomata of the leaves of the sporophytes help them to avoid the loss of water, but the low capacity to drive and store water causes restrictions to the transpiration and carbon gain, in comparison with the angiosperms (Woodhouse and Nobel 1982; Watkins et al. 2010).

Chlorophyll fluorescence data show that the sporophyte leaf possesses quantum yield values and electron transport rates similar to the other vascular plants (Maxwell and Johnson 2000). The maximum quantum yield or predawn yield of the arborescent cloud forest ferns is at the optimum value of most non-stressed plants and is similar to the arborescent ferns of humid forests, non-arborescent terrestrial ferns of tropical and humid forests, and epiphytic ferns of tropical forests (Durand and Goldstein 2001; Zhang et al. 2009; Huang et al. 2011), but it is slightly larger than that of arborescent ferns of sclerophyllous moist forests (Volkova et al. 2010). On the other hand, the maximum quantum yield of the unstressed fronds of the epiphytic ferns of a cloud forest was scarcely less than that of tree ferns coexisting in the same forest and of epiphytic ferns in a tropical rainforest (Zhang et al. 2009). The apparent maximum rate of electron transport (ETRmax) of the tree ferns *Alsophila firma*, *Cyathea divergens*, and *Lophosoria quadripinnata* of a cloud forest was low compared to species of environments with high light availability, such as semi-deciduous rainforests and sandy coasts (Geβer et al. 2005, 2008; Riaño and Briones 2013) and sun ferns (Wong et al. 2012); however, they showed similar values to the highest values of ETR or ETRmax of arborescent and herbaceous ferns of the temperate rainforest and temperate evergreen forest (Bystriskova et al. 2011; Saldaña et al. 2010; Wong et al. 2012). The ETR light saturation values of the tree ferns *Alsophila firma*, *Cyathea divergens*, and *Lophosoria quadripinnata* of a cloud forest were lower than those of sunny environments (Geβer et al. 2005, 2008; Riaño y Briones 2013) but similar to those of three species of the genus *Blechnum* growing in an open canopy in a temperate evergreen forest (Saldaña et al. 2010).

The CO_2 assimilation rate of sporophytes ranges between 0.6 and 15 μmol $m^{-2}\ s^{-1}$, which is similar to that of vascular shade plants (Hietz and Briones 2004; Hietz 2010; Mehltreter et al. 2010). The maximum photosynthesis (Amax) of three tree fern species of a cloud forest was higher than Amax of the moss, similar to that of other terrestrial fern species occupying closed sites and shaded leaves of deciduous trees, and less than that of tree ferns of the humid forest, epiphytes of exposed sites, and tropical and herbaceous trees C_3 and C_4 (Durand and Goldstein 2001; Larcher 2003; Hietz and Briones 2004; Lüttge 2008; Volkova et al. 2010; Riaño and Briones 2013). The Amax of the epiphytic ferns of the deep shadow group of a cloud forest was similar to that of mosses, shadow epiphytes, and terrestrial ferns of closed sites, while the Amax of the epiphytic ferns of the exposure group was similar to other epiphytes of the same group and the Amax of the epiphytic ferns of the exposure and tolerant groups was similar to the Amax of terrestrial ferns of closed sites and shade leaves of deciduous and tropical trees (Hietz and Briones 2001). Zhang et al. (2009) also found no differences in Amax between two species of epiphytic ferns and two species of terrestrial ferns in a tropical rainforest. Riaño and Briones (2013) showed that the density of photosynthetic flux to saturation of photosynthesis (PPFDsatA) of tree ferns *Alsophila firma*, *Cyathea divergens*, and *Lophosoria quadripinnata* of a cloud forest growing in a closed site was similar to that of shade plants, other terrestrial and arborescent ferns of closed sites, and shadow epiphytes, indicating the efficiency of tree ferns to absorb the scarce available light and assimilate CO_2 in shaded habitats by the canopy (Durand and Goldstein 2001). The PPFDsatA of the epiphytic ferns of a cloud forest was higher than that of shade plants and terrestrial ferns of closed sites, but the light compensation point (LCP) of the epiphytic ferns was similar to that of both groups (Hietz and Briones 2001). Despite their low photosynthetic rate, possibly the result of a deficiency of nutrients, the high PPFDsatA values of the epiphytic ferns of the cloud forest allow them to take advantage of high amounts of light in the hours or areas with high light in the canopy. On the other hand, the low LCP values of the epiphytic ferns make it easier for them to assimilate carbon during the frequent cloudy days or when they grow in shaded places in the canopy forest (Briones and Hietz 2001). Three herbaceous ferns of the genus *Blechnum* of a temperate forest that differ in the range of the light environment that they occupy in the undergrowth adjusted the leaf area in correspondence with the habitat that they occupied, being more plastic the species with greater ecological amplitude, but they did not show differences in the rates of CO_2 assimilation and respiration in the dark (Saldaña et al. 2010). In a New Zealand tropical forest, two tree ferns with a fast height growth rate of the genus *Cyathea* had high electron transport rates, in comparison with two species of the same genus and *Dicksonia squarrosa* (Bystriakova et al. 2011).

Like other plant species, the arborescent ferns of the cloud forest respond to the decrease in water availability by decreasing their water potential, possibly due to the increase in transpiration and/or decrease in water conduction by the stems, and their leaves thickening in the dry season (Riaño and Briones 2013). The decrease of the hydric state of the arborescent ferns of the cloud forest can be caused by the relatively high temperature and evaporative demand of the air during the dry season, in addition to the decrease of the hydric potential of the soil. However, even in the dry season, the soil water potential of a cloud forest can remain high, between −0.01 and −0.26 MPa. The decrease in water potential of the arborescent ferns *Dicksonia antarctica* and *Cyathea australis* of a sclerophyllous wet forest in response to the sudden exposure of high levels of light was not associated with changes in water availability, but probably with an increase in transpiration due to the increase in leaf temperature and possible decrease in water conduction (Volkova et al. 2009). The epiphytic ferns of a cloud forest that tolerate deep shade and grow at the base of the trunks showed no obvious adaptations to cope with drought (Hietz and Briones 1998). The leaves of *Trichomanes bucinatum* were completely dried after a few hours in moderately dry air, and the low ability to contain water caused the quantum yield to decrease faster compared to the epiphytes that grow in more exposed sites (Hietz and Briones 2001). Despite losing more than 90% of the relative water content, the quantum yield of *T. buccinatum* was able to return to half its capacity in less than 5 min and up to 90% after 1 h. Most of the plants that inhabit the canopy show adaptations to the xeric environment (Benzing 1990). The shade-tolerant and exposure-tolerant epiphytic ferns of a cloud forest showed leathery leaves, succulent rhizomes, low rates of uncontrolled water loss, leaf scales, and high cellular elasticity (Hietz and Briones 1998). The flow of water from the atmosphere to the leaves could be an important source of water for cloud forest ferns, but the cuticle of the leaves being very efficient for the control of water loss could be limiting for the absorption of liquid water or water vapor. Both the epiphytic ferns of the tolerant type and the exposure type of the cloud forest showed values of total water potential similar to those of the epiphytic bromeliads (Hietz and Briones 1998). The epiphytic ferns of the exposure type of a cloud forest diminished their values of total water potential in response to the drought, in comparison with the ferns of the tolerant shade type (Hietz and Briones 1998). Most vascular plants close their stomata before loss of cell turgor with increasing drought; however, the epiphytic ferns of the exposure group of a cloud forest had the capacity to tolerate the loss of water beyond the point of turgor loss before the stomatal closure (Hietz and Briones 1998).

In conclusion, the spores of the ferns have mechanisms to detect the environment and initiate germination when conditions are favorable in the cloud forest. The specialization to humid habitats of the gametophyte of tree ferns possibly restricts the distribution of that group to humid places. The physiological tolerance of the gametophytes of the epiphytic ferns of the cloud forest is practically unknown. The differences in the plasticity and relatively high physiological tolerance of the sporophyte facilitate the coexistence of the fern species in the cloud forest. The physiological performance as shade plants of terrestrial and epiphytes ferns makes them vulnerable to fragmentation and changes in the use of the land in the cloud forest.

23.5 Functional Diversity in the Tropical Rainforest: *Piper*, a Case Study

The tropical rainforest (TRF) is one of the most complex ecosystems and supports the highest biodiversity and productivity on earth. This forest is found along the equatorial region, where climate is more stable, hot, and wet. In Mexico, TRF has an extension of 91, 566 km^2 (4.7%), representing 45% of its original surface. Since 1960 its importance as a natural resource and the high rate of fragmentation and decrease of its original surface raised the necessity to study the biodiversity and the dynamics of change and regeneration of the TRF as the basis for restoration and conservation alternatives.

Natural disturbance, produced by gaps formation, and succession of TRF are dynamic processes in which spatial and temporal variability of the light environment plays a fundamental role, becoming a selective factor for plant attributes of these communities. To understand these processes, in 1970, Gómez-Pompa et al. initiated a series of ecological and ecophysiological pioneer studies of TRF plants at "Los Tuxtlas," a biological reserve in Veracruz, Mexico, and proposed a model to study its dynamics and to establish the scientific basis for future conservation (Gomez-Pompa et al. 1972). The theoretical framework of the research was published in the paper "The tropical rainforest: a non-renewable resource" published in 1972. The approach to fulfill their goal included ecological and physiological studies of species with differential distribution in diverse successional stages. Considering the high biodiversity of the TRF, they selected a group of species of the genus *Piper* as a model system to understand functional diversity and its ecological importance (Gómez-Pompa et al. 1976; Gómez Pompa and del Amo 1985; Field and Vázquez-Yanes 1993).

Piper species have a worldwide distribution, containing a high number of species. At "Los Tuxtlas" reserve, *Piper* has 12 species differentially distributed in habitats with variable light availability and successional stages (Gómez-Pompa 1971; Fig. 23.3), becoming a good system to study the mechanisms underlying the distribution of TRF species, as well as the ecological and evolutionary meaning of

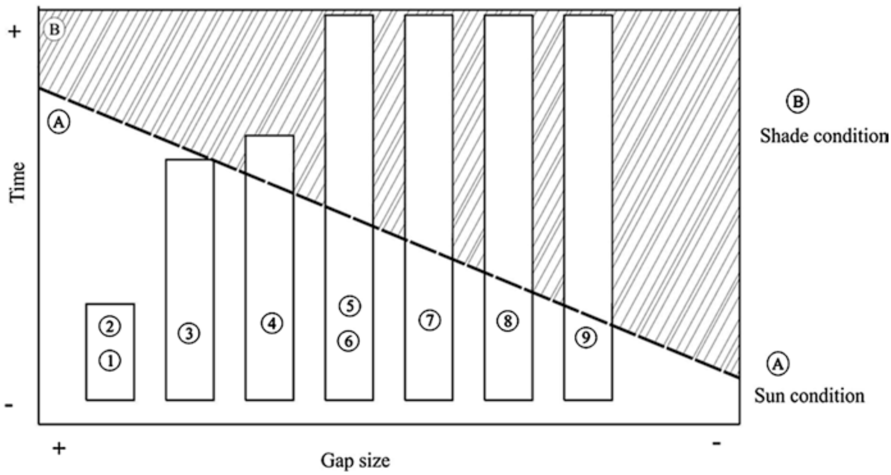

Fig. 23.3 Temporal and spatial distribution of nine *Piper* species of the tropical rainforest at Los Tuxtlas, Veracruz, Mexico. The *bar* indicates the amplitude of distribution of the species under different light environments along time and gap size axis. Species are indicated by numbers: (1) and (2) *Piper umbellatum* and *P. peltata*, (3) *P. auritum*, (4) *P. aduncum*, (5) and (6) *P. hispidum* and related forms of the species, (7) *P. amalago*, (8) *P. lapathifolium*, and (9) *P. aequale*. (Figure modified from Gómez-Pompa and Vázquez-Yanes 1985)

physiological and morphological responses of plants to light (Gómez-Pompa et al. 1971; Field and Vázquez-Yanes 1993). The studies initiated addressing the ecophysiology of germination and further were diversified to several topics including seedlings survival, establishment, photosynthesis, mineral nutrition, and growth (Vázquez-Yanes 1976, 1985; Field and Vázquez-Yanes 1993). These studies generated a great interest for ecophysiological studies of the TRF plants in Mexico and other countries (Denslow et al. 1990; Field and Vázquez-Yanes 1993; Nicotra et al. 1997). Furthermore the studies provide the basis for understanding the mechanisms of TRF species for adaptation to different rainforest habitats and their relation with the species distribution and role in ecological succession.

23.5.1 Physiology of Germination

Tropical rainforest pioneer species produce small seeds that may persist in the rainforest floor, until a canopy disturbance originates a gap and favorable conditions for their germination and establishment. The studies of germination of *Piper*, and other pioneer species from Los Tuxtlas Veracruz, in response to light and temperature clearly establish the role of light quality and temperature on the control of germination of photoblastic species (Vázquez-Yanes and Smith 1982). The studies have also provided a better understanding of the mechanisms of light use and acclimation in TRF plants, as well as its importance for species distribution in different successional stages (Vázquez-Yanes and Orozco- Segovia 1987, 1990).

Piper species produce a large number of small seeds with specific light requirements for germination. The seeds are nondormant after dispersal, and under appropriate light, temperature and humidity conditions may germinate immediately. However, if seeds are dispersed in the rainforest floor or buried in the soil, germination is inhibited by enforced dormancy and remains viable for more than 1 year, until light and/or temperature conditions trigger germination (Orozco-Segovia and Vázquez-Yanes 1990; for a review see Vázquez-Yanes and Orozco-Segovia 1993). Photoblastic seeds sense the light environment through phytochrome pigments, which function as a signal-transducing photoreceptor of light quality. Phytochrome has two forms: an active form (Pfr) and one inactive (Pr) which are interconverted by the amount of red and far-red light in the environment (R/FR ratio); this ratio increase when canopy opens, triggering seed germination, and modulating development and growth of plants (Vázquez-Yanes and Smith 1982; Orozco-Segovia and Vázquez-Yanes 1989).

In mature forest, when the canopy opens by natural or anthropogenic disturbance, changes in the daily temperature alternation in the soil and changes in the amount and quality of the light reaching the ground are detected by seeds. The fine perception sensing these changes in their surroundings allows the seeds to recognize the arrival of specific favorable conditions for germination and establishment (Vázquez-Yanes 1976; Vázquez-Yanes and Orozco-Segovia 1993).

Although for germination and establishment all *Piper* species are triggered by light, seeds of pioneer trees common in secondary forest such as *Piper auritum*, *P. sanctum*, *P. aduncum*, *P. marginatum*, *P. umbellatum*, and *P. aff. yzabalanum* require large gaps for dormancy break and germination. On the other hand, *P. lapathifolium*, *P. nitidum*, and *P. amalago*, species common in mature forest, have partial photoblastism, larger seeds, and short viability. *Piper hispidum* is the more plastic species; its seeds germinate in a wide range of light conditions, from shade of the understory to secondary forest, and it can be found in all these successional stages (Vázquez-Yanes and Orozco-Segovia 1982; Orozco-Segovia and Vázquez-Yanes 1989).

Piper seedlings growth rates also reflect their differential ability to develop under contrasting light conditions. A study on growth responses of *P. aequale*, *P. auritum*, and *P. hispidum* seedlings to contrasting natural and experimental light environments reveals that *P. auritum* had the best growth response under high light; *P. aequale* grew better at intermediate light levels, whereas *P. hispidum* showed more plasticity and grew well along the whole range of light conditions (Sanchez-Coronado et al. 1990). This study reveals how the species have a different degree of adaptation in physiological traits to germinate and grow in gaps of different size.

23.5.2 Photosynthesis and Light Environment

The light environment of the TRF is characterized by high spatial and temporal variability. The light varies from full sun in large gaps, open areas, and top of the canopy to less than 5% of full sun in the understory; spatially, light levels also varied according to gaps size. Although understory is characterized by low light conditions, short periods of direct light (sunflecks) that pass through the canopy openings reach the plants, making their light environment highly dynamic with a widely temporal variation, from few seconds to minutes; sunflecks also present a high variation in peak photon flux density (Chazdon 1988).

Photosynthetic capacity among *Piper* species varied according to their ability to grow under different light conditions (Walters and Field 1987; Chazdon et al. 1989). Large gap species show leaves with the highest photosynthetic capacity, taking advantage of the high light found in these environments; this capacity is combined with high leaf area, high nitrogen content, and short leaf life span (<1 year). On the other hand, understory species have leaves with the lowest photosynthetic capacity, small area, lower nitrogen content, and longevity of 3–5 years (Chazdon et al. 1989, Table 23.3). Differences among species in the way they gain and invest their resources allow *Piper* species to fall in a continuum between photosynthetic maximization on one side and cost maximization on the other (Field and Vázquez-Yanes 1993). *P. hispidum*, one of the species with wider distribution in different light conditions, produced leaves with photosynthetic and cost features nearly along the entire range; leaf longevity also showed plasticity lasting from 6 months to 2 years (Field and Vázquez-Yanes 1993).

Table 23.3 Photosynthetic, structural, and environmental characteristics of leaves of six *Piper* species

Characteristic	Species						
					P. hispidum		
	P. aequale	*P. amalago*	*P. lapathifolium*	*P. auritum*	Clearing	Understory	*P. umbellatum*
Amax/area (μmol CO_2 $m^{-2}s^{-1}$)	2.61 ± 0.08	2.65 ± 0.16	3.04 ± 0.13	9.53 ±0.50	9.61 ± 1.29	3.48 ± 0.11	6.14 ± 1.16
Amax/mass (nmol CO_2 $g^{-2}s^{-1}$)	71.80 ± 1.93	73.95 ± 5.08	97.05 ± 3.17	344.75 ± 21.82	192.61 ± 26.63	132.24 ± 6.84	87.86 ± 37.66
PPNUE (mol CO_2 $N^{-2}s^{-1}$)	36.16 ± 1.24	43.09 ± 2.47	49.61 ± 1.51	126.65 ± 5.75	90.07 ± 9.70	56.46 ± 2.71	92.16 ± 11.44
N/area (mmol N m^{-2})	72.45 ± 1.15	61.60 ± 1.12	61.13 ± 1.43	74.84 ± 1.76	102.41 ± 4.31	70.92 ± 2.01	64.95 ± 6.02
N/mass (mmol N g^{-2})	1.99 ± 0.05	1.70 ± 0.04	1.95 ± 0.02	2.68 ± 0.07	2.02 ± 0.09	2.34 ± 0.05	1.97 ± 0.21
LSM (g m^{-2})	36.46 ± 0.89	36.26 ± 0.71	31.29 ± 0.78	28.06 ± 0.68	51.52 ± 2.09	30.30 ± 0.89	33.21 ± 90.93
Canopy openness for leaf (%)	6.58 ± 0.61	4.53 ± 0.28	5.14 ± 0.34	35.20 ± 1.71	23.74 ± 2.96	5.12 ± 0.49	20.77 ± 3.26
Measured daily PFD (mol m^{-2} d^{-1})	0.36 ± 0.09	0.70 ± 0.16	0.41 ± 0.04	13.54 ± 1.39	9.44 ± 1.86	0.32 ± 0.04	15.28 ± 2.72

Table modified from Chazdon and Field (1987)
Values are means ± s.e
Amax maximum assimilation rate, *PPNUE* photosynthetic nitrogen use efficiency, *LSM* leaf-specific mass, *N* nitrogen content, *PFD* photon flux density

Sunflecks represent an important resource for understory plants, as they provide 10–80% of the total photon flux density available for photosynthesis (Chazdon 1988). For *Adenocaulon bicolor*, an understory herb, 30–70% of the total daily carbon gain occurs during sunflecks (Pfitsch and Pearcy 1989). Therefore the capacity of understory plants to utilize this resource may have a strong influence on their growth and reproduction (Pfitsch and Pearcy 1989).

The ability of plants to utilize sunflecks depends, at a physiological time scale, on the photosynthetic induction state, a process determined by the response dynamics of photosynthetic enzymes and stomatal opening. The completion of the induction process may last 20 min under continuous high light, but it may be able to be attained under dynamic light conditions (Pearcy 1990). When a sunfleck arrives at the leaf surface of an understory plant, an increase in CO_2 assimilation occurs, and it continues for at least 1 min after the sunfleck has passed as post illumination CO_2 fixation; the state of induction before the sunfleck determines the maximum assimilation rate during the sunfleck (Pearcy 1990).

The role of dynamic stomatal and biochemical responses to variable light on carbon gain was studied in two *Piper* species with contrasting distribution: the pioneer tree, *P. auritum*, and a shade-tolerant shrub, *P. aequale*. The species where acclimated to high and low light to determine the influence of photosynthetic acclimation on dynamic photosynthetic responses.

Results showed that acclimation to contrasting light environments had a significant effect on stomatal response dynamics; for both species, the integrated stomatal conductance (g_s) response to lightflecks was smaller when plants were acclimated to a light regime different to its natural environments (Tinoco-Ojanguren and Pearcy 1992, Fig. 23.4).

The steady-state and the dynamic responses of CO_2 assimilation (A) and g_s to light (light curves and lightflecks, respectively) showed contrasting results; for

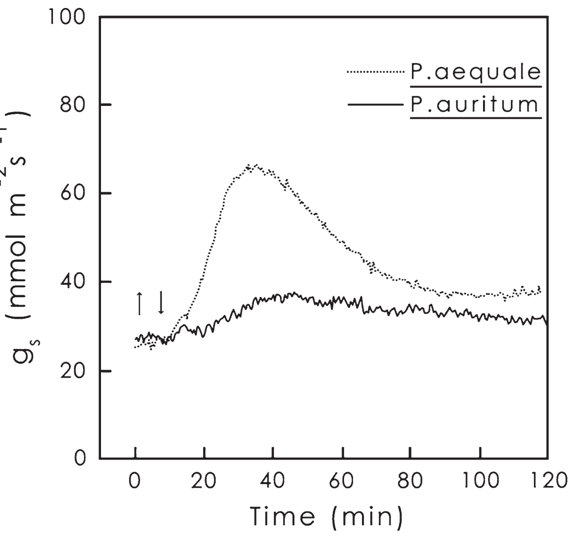

Fig. 23.4 Representative time course of the stomatal responses, of shade-acclimated plants, to a lightfleck of 4 min duration. *Arrows* indicate the time when PPFD was increased and decreased

shade-acclimated plants, the steady-state responses were identical; in contrast, the response to lightflecks was significantly different (Tinoco-Ojanguren and Pearcy 1992). The shade-tolerant species *P. aequale* showed larger and faster g_s response than the gap species *P. auritum*. The response of *P. aequale* allowed this species to keep higher g_s and intercellular CO_2 concentration during a series of consecutive lightflecks and therefore improves assimilation by 30–200%, depending on the sunfleck duration. In comparison, the gap species presented a small stomatal response to lightflecks and no improvement in C gain. In contrast for high light-acclimated plants, g_s response to lightflecks was greater in *P. auritum* than *P. aequale*.

Vapor pressure deficit (VPD) had a significant effect on the stomatal response to lightflecks. Increases in VPD had decreased the magnitude and dynamics of the response, exhibiting a more conservative behavior in terms of water loss, at the expenses of carbon gain. The effect was different among species and between sun- and shade-acclimated plants. Sun plants of *P. auritum* were more sensitive to VPD (Tinoco-Ojanguren and Pearcy 1993). These results suggest a possible adaptive significance of the stomatal response for the species studied. Shade-acclimated plants of *P. aequale* showed a stomatal response that would be expected for a species that maximize C gain in an environment where light is the main limiting factor. Sun acclimated plants of *P. auritum* had a stomatal behavior that would be expected for a species that maximizes C gain and water loss in an environment where light is not limiting but water stress may be an important limitation.

23.6 Implications of Functional Diversity in Conservation

The case studies presented in this chapter are just an example of plant functional diversity found at different phases of their life cycle and at different complexity levels. There is still the necessity for increasing our knowledge to predict how climatic change, fragmentation, land use change, introduction of exotic plants, and other anthropogenic disturbances are affecting most species directly or indirectly, as many biotic interactions are affected by these disturbances. The importance of knowledge on functional traits for conservation issues has led to propose a research discipline: conservation physiology, which has been defined in a broad sense as a scientific discipline that encompasses functions and mechanisms at all scales (from molecules to biosphere) and their responses to environmental changes; it also includes the development of strategies to understand, manage, and restore populations and ecosystems (Cooke et al. 2013). This definition assumes that for real advancements in conservation and resources management, this discipline must also be integrative with other disciplines. In a rapidly changing world, efforts should be focused to the responses of plant species (including invasive species) to environmental changes to develop models for well-characterized functional diversity for management and restoration proposals, especially for keystone species, vulnerable species such as epiphytes, rare and endemic species, and some seedlings that require host trees and nurses.

Mexico has provided to the world several globally important cultivated plants such as maize, beans, cacao, prickle cactus, and tomato, which are the result of selection from its high plant diversity, together with the empirical botanical knowledge of its inhabitants. Presently, there is a pressing need to understand physiological mechanisms that led this diversity of cultivated plants and their ancestors to persist and an urgency to implement management practices for its conservation.

Plant physiological research in Mexico is helping to explain questions of interest at various scales, from molecules (Vargas-Soto et al. 2009; Ricalde et al. 2010; de la Rosa-Manzano et al. 2015; Santiago et al. 2017) to whole plant processes (Cervera et al. 2006, 2007; Riaño and Briones 2013; Riaño-Ospina et al. 2015), to communities and ecosystems (Reyes-García 2012; Cach-Pérez et al. 2013; Chilpa-Galván et al. 2013; Méndez-Barroso et al. 2014; Sanaphre-Villanueva et al. 2017), for functional diversity of seeds and its application to restoration (Orozco–Segovia and Sanchez– Coronado 2009).

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Chapter 24
Realities and Pending Issues in the Scientific Research in Natural Protected Areas in Mexico

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Social and environmental irrationality in the small territories has caused global damages inducing global warming.
(Toledo 2015)

Abstract In order to offer useful recommendations for sustainable management of natural protected area(s) (NPA) in Mexico, scientific research should address not only ecological but also economic and social aspects as well. For most part, all NPA or to be designated NPA in Mexico have some anthropogenic interaction or a human settlement, and the majority live in poverty. Management of NPA should include poverty relief and livelihood alternatives developed specifically for the local populations. This work emphasizes the aspects of scientific research in Mexican NPA that need to be developed. It stresses the need for multidisciplinary and multi-institutional scientific research related to sustainable use of natural resources and updates information related to NPA integration. To obtain a sustainable bio-cultural heritage, the information provided supports CONANP efforts to integrate its sustainability model of nature with human capital to improve performance of NPA. To this end, scientific research in NPA is indispensable, for it is the only "in vivo laboratory model" available to test public sustainability policies not only for the protected area but also for the survival of the planet. This is the ultimate goal of the National Network of Protected Natural Areas (RENANP-CONACYT).

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24.1 Introduction

The evolution of the species originated biodiversity on the planet, and in so doing, man acquired the power to transform its environment; however, this has caused incalculable damage to the environment. In this regard, the United Nations (UN), in its report in the Conference on the Human Environment, stated that the evidence of man-made or man-induced damage to the land includes “dangerous levels of pollution to water, air, land and living organisms; major disruption of the ecological balance of the biosphere; destruction and depletion of irreplaceable resources...” (UN 1973). In response, international organizations, governments, and academic institutions have applied methods of conservation of natural resources through the creation of public policy instruments, such as natural protected area(s) (NPA), with the objective of the conservation of biodiversity.

The establishment of NPA begins in the United States with the creation of Yellowstone National Park. In the late nineteenth century and since that time, it has become the main legal tool of environmentalists for protecting an ecologically important system. In Mexico, the process of creating NPA begins in 1917, with the Desierto de los Leones National Park, which continued in the administration of Lazaro Cardenas (1934–1940), where about 30 national parks were established (Riemann et al. 2011).

The General Law of Ecological Balance and Environmental Protection (LGEEPA) regulates the administration of NPA in Mexico. Many if not all NPA have anthropogenic influence by being near or having actual human settlements. Establishment of a NPA does not stop human interaction or lead to eviction of the people that may be living there. For example, in biosphere reserves, it is expected that the local population perform activities that involve care taking and managing of natural resources (Chamber of Deputies of the Mexican Congress 2016, art. 48).

Thus, we see that NPA in Mexico provide species biodiversity but also have indissoluble anthropogenic influence of some form, including human settlements. Environmental public policy seeks sustainable development integrated with society, in order to provide economic development and environmental preservation. NPA provide ecosystem services and economic and social benefits, as well as ancestral cultural dynamics transmitted from one generation to the next. Thus, NPA conserves biodiversity by providing some benefit to the local inhabitants. However, the neoliberal stance of the capitalist society is to industrialize and irrationally waste out natural resources, which is contradictory to biodiversity conservation (De la Rosa Velazquez et al. 2017). Therefore, NPA should strengthen their management programs to ensure the achievement of sustainable development.

As previously mentioned, almost all NPA or those with potential to be designated as NPA have some form of human settlement, typically living in poverty. In addition, the common practice of decreeing a NPA in the past has excluded populations in the decision-making process. This unilateral imposition can translate into social unrest. Therefore, in the creation process of a NPA in order to conserve an ecological landscape, it requires not only good use and management of natural resources by population, with their participation and links with the institutions responsible for conservation, so that their voices can be heard (Martinez-Alier et al. 2010; Halffter 2011).

In this sense, scientific research for NPA in Mexico should address all issues that arise around it and contemplate both conservation and social aspects such as some ecological deterioration. For example, management of NPA should include poverty relief and livelihood alternatives developed specifically for the local populations. Hence, there is a need to analyze the current situation of a NPA in terms of its outstanding issues related to the local population. This should be done in order to develop these areas in order to achieve sustainable development without disconnecting the natural dimension from the economic and social.

The work presented here aims to emphasize those aspects of NPA that need to be developed through scientific research. This work was possible thanks to the participation of expert researchers on the topic of NPA that are administratively responsible for the region under the auspices of the National Commission of Natural Protected Areas (CONANP). Before analyzing the state of research of NPA, aspects of climate change and sustainable development are addressed first in order to provide a richer framework for understanding, and then subsequently, the work of the National Network of Protected Areas is addressed (RENANP) and, along with the statistical aspects of NPA in the country, is presented.

24.2 Protected Areas, Climate Change, and Sustainable Development

To cope with the demand for water, food, and fuel, in the last 50 years, economic activities have changed ecosystems. The consequence has been loss of biodiversity and climate change, which poses an obstacle to ensure sustainability and reduce hunger, which are targets of the Millennium Development Goals of the United Nations, which Mexico joined in 2000 (Millenniunm Ecosystem Assessment 2005).

In this regard and noting that climate change modifies ecosystems, NPA serve as instruments to address biodiversity loss, since uncontrolled growth of the human population has damage to the environment, deforestation, and other habitat maladies (Lopoukhine et al. 2012). For its part, the International Union for Conservation of Nature (IUCN) refers to these areas as "a recognized geographical area ... defined, dedicated and managed, through legal or other effective means to achieve long-term nature conservation and its associated ecosystem services and cultural values" (Dudley 2008).

In this regard, the National Commission of Natural Protected Areas (CONANP) consider NPA to be sovereign areas that belong to the nation, where the original environment has not been modified by human activity or need to be preserved and restored. These areas are derived from a presidential decree, and the activities carried out in them adhere to the General Law of Ecological Balance and Environmental Protection (LGEEPA) and its regulations and conservation programs and respective management (CONANP 2016).

Also, NPA can be safeguarded through management actions and management of natural and social resources contained therein (Pinkus et al. 2014). In order to provide benefits to communities close to them and to promote their welfare and development. So that their areas of influence are made by communities with which they maintain close social, economic, and ecological interaction, where the uses and activities of exploitation of natural resources, sustainable development, and environmental protection are addressed (Chamber of Deputies of the Mexican Congress 2014).

In this sense, NPA are enacted with the aim of promoting a balanced relationship between people and nature in order to achieve sustainability. This development has been molded through various international events, thanks to inputs from the United Nations Conference on the Human Environment, held in Stockholm, Sweden, in 1972. They proposed the proper management of natural resources and reducing the growth rate of the world population (Tetreault 2008) and the "Brundtland Report," which defined using resources as follows: "to meet the needs of the present without compromising the ability of future generations to meet their own needs" (1987).

For its part, Mexico in 1993 signed the Convention on Biological Diversity (CBD), derived from the Earth Summit, for sustainable use of natural resources and the equitable sharing of benefits derived. Later, in 2002, as a result of the country's participation in the Johannesburg Summit, recognition of indigenous practices, as a key element of sustainable development (Mendez Escobar 2003).

Thus, sustainable development is defined within a NPA as seeking to achieve three goals: (1) conservation of the natural resources, (2) social needs, and (3) economic development of communities within NPA. The purpose is to use natural resources without altering the ecological balance in time. Therefore, it is a priority to address the basic needs of the poor, toward achieving greater social equity.

24.3 The Role of the National Network of Protected Natural Areas in the Investigation of the Areas Concerned

Attentive to sustainable development that needs to be achieved within NPA, the National Network of Protected Natural Areas (RENANP) created the goal of developing scientific research addressing the management of these areas, in a comprehensive and transdisciplinary way, and identifying gaps to fill in field study of them, with a view that the development in question is not lost sight of.

As such, the RENANP, considered imponderable, promotes the development of professional associations, officials, students, and researchers, who, from their field of study, contribute and generate scientific knowledge about NPA. It seeks to encourage greater participation by the scientific community and decision-makers from various branches of the organizational structure of public administration, which will influence the design and implementation of environmental public policies, focused on NPA.

RENANP, promoted by the National Council of Science and Technology (CONACYT) by researchers from various disciplines and attached to higher education institutions and research centers, seeks to work in the generation of multidisciplinary knowledge. This knowledge incorporates both biodiversity conservation and the rational use of natural resources, along with sustainable development of communities within the aforementioned areas and their zones of influence (RENANP 2018). This way and from the circumstances described, for example, diagnoses concerning the challenges and opportunities for NPA in Mexico are performed.

The common elements that bring together the authors of this contribution are NPA and the slope to cover for the same, in generating scientific knowledge, to delve into the social aspects enclosed in environmental issues and agenda in such areas. Therefore, the aim of this chapter is to analyze and reveal what is the current situation around NPA in Mexico and, from there, to identify whether scientific research developed in these areas is being addressed in the country and to recommend research topics that need to be addressed.

This does not translate to considering that research to date have been developed around NPA, insufficient or unfinished, but on the contrary, it means that they represent spearheads regarding the generation of new knowledge by scientists that still remain to be addressed and that integrate future outlook of what is expected by the scientific community to NPA.

24.4 Methodological Strategy

Based on information distributed by the National Commission of Natural Protected Areas (CONANP), the current statistical context, NPA is presented in Mexico, aspects such categories thereof, the total proportional amount, surface land in hectares, administrative regions grouped and the number and percentage of NPA, which constitute, along with the types of ecosystems. This was done in general through the analysis of scientific research generated by each administrative region, which contrasted with those aspects and needs that have not been addressed within the NPA.

Also, research topics regarding NPA are proposed to be carried out as a priority, in particular, as in those where the common denominator is the absence of program management, management plan, or the need for social knowledge generation.

To accomplish the above, during the months from October to December 2017, a comprehensive review was carried out using information held in different databases such as Proquest, Ebsco, Dialnet, Redalyc, and national repository CONRICyT. Through qualitative content analysis of the information, the presence of the topics of interest was identified and from there interpretation proceeded. The findings were compared by conducting several workshops and analyzing each reported research result obtained from each CONANP administrative region. The information generated allowed for integrating a database, which in turn led to identification and classification of priority research topics/themes to develop in a particular NPA.

24.5 Results and Discussion

24.5.1 Characteristics and the Current Status of Protected Areas in Numbers

According to data released by the National Commission of Natural Protected Areas (CONANP), in November 2017, authority was responsible for managing 182 NPA in the country (CONANP 2018), as well as integrating different categories (Fig. 24.1).

In Fig. 24.1 are described management categories established by the CONANP for NPA in Mexico, as well as those provided by the General Law of Ecological Equilibrium and Environmental Protection (LGEEPA) in its Article 46 (Chamber of Deputies of the Mexican Congress 2016). It should also be noted that from 182 NPA existing in the country, most are part of national parks (NP), with natural monuments (NM) representing the minority (Fig. 24.2).

The percentages in Fig. 24.2 show that in addition to the category of national park (NP), those of biosphere reserve (BR) and area for protection of flora and fauna (APF&F) occupy the second and third place, respectively, in terms of total NPA that

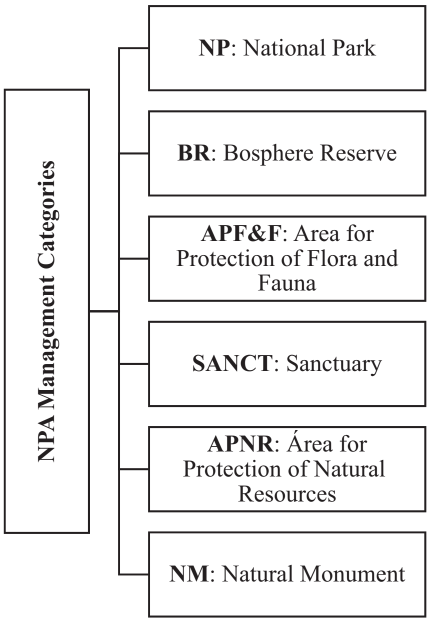

Fig. 24.1 Categories of natural protected areas (NPA). (Source: Prepared from information provided by CONANP 2018)

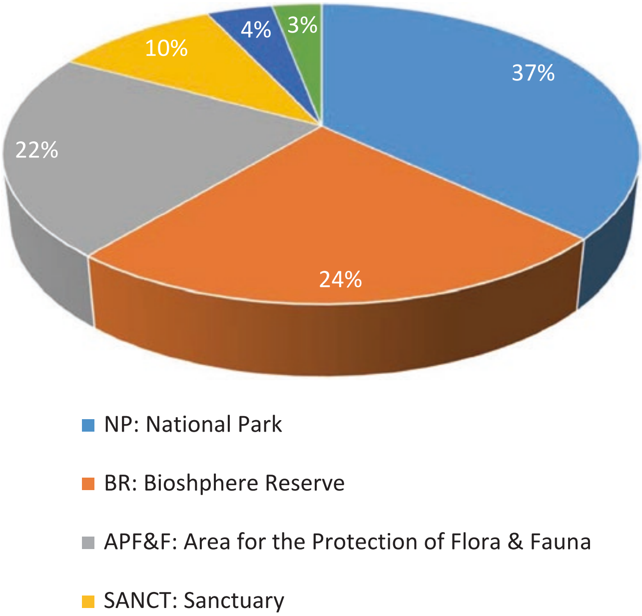

Fig. 24.2 Percentage of protected areas in the country, management category. (Source: Prepared from information provided by CONANP 2017)

Table 24.1 Surface in hectares of NPA management category

Management category and number of NPA		Surface ha	Percentage of surface
BR	44	62,952,750.5	69.3%
NP	67	16,220,099.3	17.86%
APF&F	40	6,996,864.12	7.7%
SANCT	18	150,193.29	0.17%
NM	5	16,269.11	0.02%
APNR	8	4,503,345.23	4.96%
Total	182	90,839,521.55	100%

Source: Prepared using information from the CONANP 2017

exist in the country. Regarding surface area comprising NPA, by category, they represent 90,839,521.55 ha. The total national territory consists of 196,018.900 ha (Table 24.1).

NPA total in the country, not only is it likely to be classified according to management categories identified in advance, are also grouped into a total of nine regions (Federal Executive Branch 2007). For administrative purposes, the country is divided into nine regions, and they are Region of the Baja California Peninsula and North Pacific (RPBC), Northwest and Upper Gulf of California (RNOAG), Northern Region and Sierra Madre Occidental (RNSOC), Northeast Region and Sierra Madre Oriental (RNESOR), Gulf of Mexico Region and Coastal Plain

Table 24.2 Administrative regions of CONANP and the states of Mexico that integrate

No.	Administrative regions of CONANP	Mexican state(s) where the reserve is located
1	RPBC	Baja California and Baja California Sur
2	RNOAG	Sonora and Sinaloa
3	RNSOC	Chihuahua, Durango, and Zacatecas
4	RNESOR	Coahuila, Nuevo Leon, and San Luis Potosi
5	RGMPC	Tamaulipas, Veracruz, Tabasco, and Campeche
6	RP&C	Yucatan and Quintana Roo
7	ROPC	Nayarit, Jalisco, Colima, Michoacan, Aguascalientes, and Guanajuato
8	RCEN	Guerrero, Morelos, Puebla, Queretaro, Mexico, Tlaxcala, Hidalgo, and Mexico City
9	RFSI	Chiapas and Oaxaca

Source: Prepared based on the agreement issued in the Official Gazette dated July 20, 2007 (Federal Executive Branch 2007)

(RGMPC), Yucatan Peninsula Region and the Caribbean (RP&C), West and Central Pacific Region (ROPC), Central and Neo-volcanic Region (RCEN), and Southern Border, Istmo and South Pacific Region (RFSI) (Table 24.2).

Table 24.2 shows the relationship between the nine administrative regions in which CONANP divides the territory of the country and the number of states included. The regions that contain more states are Central and Neo-volcanic Region (RCEN) and West and Central Pacific Region (ROPC), with eight and six, respectively. On the other hand, the Region of the Baja California Peninsula and North Pacific (RPBC); the Southern Border, Istmo and South Pacific Region (RFSI); the Northwest and Upper Gulf of California (RNOAG); and the Yucatan Peninsula Region and the Caribbean (RP&C) are the regions with a smaller number of Mexican states, with two each.

The definition of regions constitutes and represents a difficulty for the management and administration of NPA. There are examples in those regions where it can span more than one state and even among more than one administrative region of the CONANP, thus hindering consensus for the management of both human and financial resources. In addition, the extension and cultural diversity of Mexico demanded specific financial and logistics resources to achieve conservation and sustainable management of specific NPA, especially in the Southern Border, Istmo and South Pacific Region (RFSI) and the Yucatan Peninsula Region and the Caribbean (RP&C) (Pinkus Rendón 2010).

Analyzing the number of NPA by their regions, their category, and their SIMEC (Information, Monitoring and Evaluation System for Conservation) record, it was possible to notice even greater differences among regions in Table 24.3 (CONANP 2017a, b).

The three administrative regions of the CONANP with the highest number of NPA are Central and Neo-volcanic Region (RCEN), West and Central Pacific Region (ROPC), and Southern Border, Istmo and South Pacific Region (RFSI),

Table 24.3 Total number of protected natural areas, by administrative region of CONANP

Administrative region	No. of NPA	Approximate percentage of total NPA
RNOAG	9	5%
RP&C	25	13%
RPBC	18	10%
RCEN	36	20%
ROPC	27	15%
RGMPC	13	7%
RFSI	26	14%
RNSOC	11	6%
RNESOR	17	9%
Total	182	100%

Source: Prepared from information provided by CONANP (2017a)

Table 24.4 Extension of the surface of protected areas in hectares, by administrative region of CONANP

Administrative region	Surface ha	Approximate percentage of the total surface of NPA
RNOAG	2,230,372.27	2.45%
RP&C	8,562,758.05	9.42%
RPBC	43,471,482.16	47.85%
RCEN	1,729,163.60	1.90%
ROPC	15,526,963.01	17.09%
RGMCC	2,310,190.23	2.54%
RFSI	11,461,244.28	12.61%
RNSOC	2,301,009.01	2.53%
RNESOR	3,246,338.93	3.57%
Total	90,839,521.54	100%

Source: Prepared from information provided by CONANP (2017b)

representing 20%, 15%, and 14%, respectively, of the 182 total NPA in the country. Moreover, the administrative region that includes fewer NPA is the Northwest and Upper Gulf of California (RNOAG), which represents only 5% of all NPA present in Mexico. The great heterogeneity of all NPA included in each administrative region of the CONANP is evident.

We also analyzed the total surface in hectares by NPA in each administrative region of CONANP (Table 24.4).

The administrative region of CONANP, which has a larger surface area, is the Region of the Baja California Peninsula and North Pacific (RPBC). The area corresponds to about half of the 182 NPA existing in the country to date. In contrast the surface of the Central and Neo-volcanic Region (RCEN), the Northwest and Upper Gulf of California (RNOAG), and the Northern Region and Sierra Madre

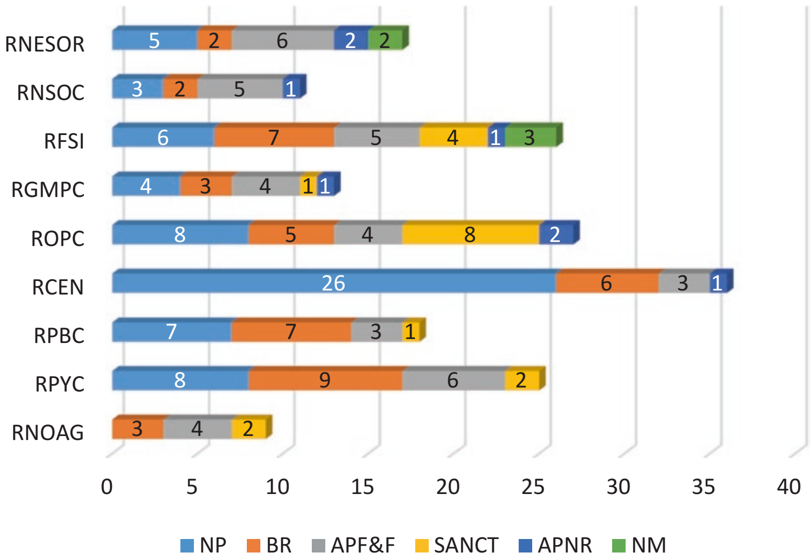

Fig. 24.3 Number of natural protected areas (NPA) within the administrative jurisdiction of CONANP by management category. (Source: Prepared from information by CONANP 2017)

Occidental (RNSOC) represents a little less than 7% of the total area of NPA in Mexico.

A comparison between the data described in Tables 24.3 and 24.4 shows that the Region of the Baja California Peninsula and North Pacific (RPBC) is the one with the largest area in hectares and in contrast the Central and Neo-volcanic Region (RCEN) has less. This fact is paradoxical because the first does have few NPA (18) and the second has the largest number of NPA (36), which is summarized in Fig. 24.3.

Figure 24.3 shows that the administrative regionalization of CONANP, reporting a greater number of NPA, is the Central and Neo-volcanic Region (RCEN), and the region holding the fewest of them is the Northwest and Upper Gulf of California (RNOAG); however, the latter is, in turn, comprising fewer categories of NPA, which are three, biosphere reserve (RB), area for protection of flora and fauna (APF&F), and sanctuary (SANCT), while that regionalization, which provides greater diversity of categories, turns out to be the Southern Border, Istmo and South Pacific Region (RFSI).

Figure 24.3 highlights the heterogeneity of the regions, which reflects the mega-diverse character of the country, including the bio-cultural diversity associated to the various types of ecosystems and to the type of vegetation in them that prevails. Types of vegetation have been classified as ecosystems by CONANP and are the following: (1) cloud forest, (2) coniferous forest, (3) oak forest, (4) deciduous forest, (5) evergreen forest, (6) dry scrub, (7) grassland, (8) hydrophilic vegetation, (9) mangrove, (10) bodies of water, and (11) other vegetation (CONANP 2016b). Also,

Table 24.5 Types of ecosystems in NPA management category

		NPA management category					
		APF&F	APRN	MN	PN	RB	SAINT
Types of ecosystems	Mountain mesophyll forest	✓	✓	x	✓	✓	x
	Coniferous forest	✓	✓	x	✓	✓	x
	Oak forest	✓	✓	✓	✓	✓	x
	Deciduous forest	✓	✓	✓	✓	✓	✓
	Evergreen forest	✓	✓	✓	✓	✓	✓
	Desert scrub	✓	✓	✓	✓	✓	x
	Pastureland	✓	✓	x	✓	✓	✓
	Hydrophilic vegetation	✓	✓	✓	✓	✓	✓
	Mangrove swamp	✓	x	x	✓	✓	✓
	Water bodies	✓	✓	✓	✓	✓	✓
	Other vegetation	✓	✓	✓	✓	✓	✓

Source: Prepared from information provided by CONANP (2016b)

in addition to the aforementioned ecosystems, there are others such as induced vegetation, coastal dune scrub, temperate forest, moors, and mangroves (Bezaury and Gutierrez 2009).

Table 24.5 summarizes the main types of vegetation present in NPA, classified by management category. Three management categories, namely, the area for protection of flora and fauna (APF&F), national park (NP), and biosphere reserve (BR), all types of ecosystems, were found, while in contrast to the category of natural monument (NM) and sanctuary (SANCT), four types of ecosystems were not present.

The data of Tables 24.4 and 24.5 warns that there are ecosystems that are more exclusive than others for certain categories of management, such as the case of mangroves, which is the highest estimated absence in three categories: protected natural resource areas (APNR), natural monuments (NM), and sanctuaries (SANCT). This highlights the importance of considering these dissimilarities, when planning the conservation in the aforementioned areas.

Also, another situation should be noted, and it is related with NPA management programs (Fig. 24.4).

Most NPA do not possess management programs; 41% of the 182 have been enacted to date. This situation is particularly urgent, since management programs are responsible for pointing out the operating rules of the area, and without them, it is impossible to ensure the achievement of sustainable development in its three dimensions, which aim to achieve the goal NPA. This is because in the absence of a document to set the permissible and prohibitive rules, then it is impossible the properly manage the sustainability of the NPA.

In this regard, the National Commission for Human Rights (NCHR) issued the General Recommendation No. 26, dated April 13, 2016, that there was a lack of management programs for NPA. This lack of generating, or updating, management programs for NPA is a failure because management programs provide certainty to

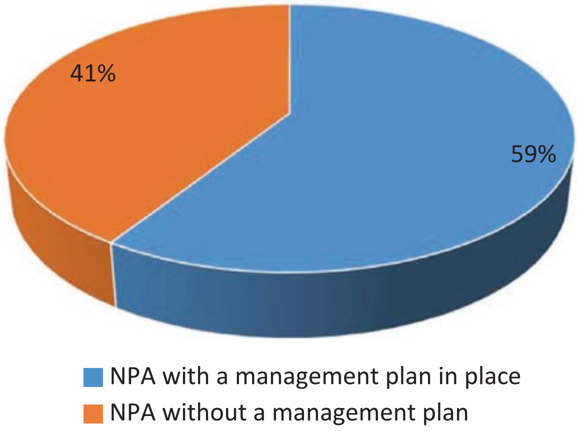

Fig. 24.4 Percentage of protected areas with and without management programs. (Source: Prepared from information provided by SEMARNAT 2017)

the federal and local authorities, as well as local populations, as they define the activities permitted, prohibited, and incompatible within a NPA. Management programs must lead the actions promoting the sustainable development. The NCHR concludes that in NPA "the lack of planning and regulation specific regulations ... have contributed to the degradation and disturbance of the same".

24.5.2 State Research in NPA of Mexico

The analyses concerning the thematic research developed in NPA allowed to note that there is a strong inclination toward the research in natural sciences (Table 24.6).

The trend of investigations of NPA has developed toward topics in the natural sciences. Of the 33 topics/themes identified (see Table 24.6), the majority (21 out of 33) were natural science related, whereas the remaining studies were related to the social sciences (7) and only 4 are multidisciplinary.

The main problem of investigations with disciplinary approach in natural science is the study of flora and fauna (Table 24.6, topic numbers 1, 3, 4, 5, 8, 11, 12, 14, 19, 25, and 26). Social science research leans toward economic and social impacts of NPA (Table 24.6, topic numbers 15 and 25). Meanwhile, in the case of research with multidisciplinary approach, the trend was toward research that linked livestock with ecosystems and natural resources (such thematic research is distinguished by the numbers 14 and 27).

Once established that the 33 research topics have been defined for NPA, we constructed Table 24.7, which shows the number of citations linked to NPA that are within the administrative jurisdiction of CONANP, using the same research topics/themes listed in Table 24.6.

The information generated for each administrative region is highly heterogeneous. For instance, the Southern Border, Istmo and South Pacific Region (RFSI) had 206 references, while the Northwest and Upper Gulf of California (RNOAG)

Table 24.6 Prevailing research themes of natural protected areas

No.	Theme	Science discipline
1.	Biology of endangered species	Natural sciences
2.	Toxic pollution	Natural sciences
3.	Domesticating plants	Natural sciences
4.	Domestication of wildlife	Natural sciences
5.	Effects of alien species	Natural sciences
6.	Effects of climate change on species	Natural sciences
7.	Effects of climate change on ecosystems	Natural sciences
8.	Invasive species	Natural sciences
9.	Pedagogical studies	Natural sciences
10.	Hydrological studies	Natural sciences
11.	Anthropological studies	Social sciences
12.	Biological studies of flora and fauna	Natural sciences
13.	Studies connectivity	Multidisciplinary
14.	Ecological studies (populations, communities, ecosystems, landscapes)	Multidisciplinary
15.	Economic and market studies for the resources used and outputs produced	Social sciences
16.	Oceanographic studies	Natural sciences
17.	Studies of food webs	Natural sciences
18.	Sociological studies	Social sciences
19.	Vegetation structure	Natural sciences
20.	Assessments of fishery resources	Natural sciences
21.	Cultural geography of the landscape	Multidisciplinary
22.	Environmental impacts by anthropogenic activity	Natural sciences
23.	Environmental impacts mining	Natural sciences
24.	Environmental impacts tourism	Natural sciences
25.	Socioeconomic impacts	Social sciences
26.	Cultural impacts	Social sciences
27.	Floristic and faunal inventories	Natural sciences
28.	Research appropriation and use of natural resources	Multidisciplinary
29.	Land use planning	Multidisciplinary
30.	Restoration of groundwater	Natural sciences
31.	Soil restoration	Natural sciences
32.	Ecosystem services	Multidisciplinary
33.	Environmental services	Multidisciplinary

Source: Constructed by authors

had only 10 of them. Also noteworthy were the regions that includes academic field stations, which allow the combined effort and transversal work involving collegial researchers and academics, such as the Reserve of Chamela (ROPC), Cuatrociénegas in the Northeast Region and Sierra Madre Oriental (RNESOR), and Los Tuxtlas region in the Gulf of Mexico Region and Coastal Plain (RGMPC) (Halffter 2011; Jimenez et al. 2014; Olmos Martinez et al. 2008).

Table 24.7 Number of investigations in NPA by administrative regions of CONANP

Administrative region of the CONANP	Number of citations	Approximate percentage of references	Develop thematic
RPBC	28	4.56%	1, 2, 5, 9, 12, 14, 15, 17, 19, 24, 25, 26
RNOAG	20	3.25%	1, 5, 15, 24, 25, 26
RNSOC	4	7.49%	1, 5, 6, 10, 12, 15, 16, 17, 18, 24, 25, 26
RNESOR	76	12.37%	1, 3, 4, 15, 24, 25, 26
RGMPC	82	13.35%	1, 2, 5, 6, 7, 12, 15, 20, 21, 23 and 24, 25, 26
RP&C	54	8.79%	1, 13, 15, 24, 25, 26
ROPC	66	10.74%	4, 8, 15, 16, 18, 24, 25, 26
RCEN	38	6.18%	1, 8, 10, 15, 16, 19, 24, 25, 26
RFSI	206	33.55%	1, 2, 5, 6, 8, 11, 13, 24, 25, 26
Total	614	100%	

Source: Constructed by authors

The more addressed topics were (a) environmental impacts generated by mining and human activities and (b) ecosystem services, floristic inventories and fauna, all belonging to the natural sciences. More than 40% of the territory of the country is under concession to mining companies, causing conflicts between such activity and the type of land use of NPA. Also, some are inserted in most NPA human populations and, for the most part, have been living there for generations before the area was designated as a NPA, with economic activities developed in these areas. It is indubitable that the activities unregulated result in some form of environmental degradation and a self-spiral population-poverty-environmental deprivation (Labandeira et al. 2007).

The ecosystem services is one of the most applied ecological research, rending specific and practical recommendations. In addition, the importance of addressing ecosystem services research is that it allows to design strategies for action, to be considered both by decision-makers in the government, and to sensitize local populations and visitors, concerning the values offering NPA.

As regards the floristic inventories and fauna, its frequency as a thematic research in NPA is due to the megadiverse character of Mexico, coupled with the disciplinary bias of the natural sciences. However, it is a priority issue, as it is necessary to "estimate the impact of deforestation on the floristic diversity and ecological processes" (Guevara and Halffter 2007). Despite their frequency, there is still no full inventory of the taxonomic elements enclosing NPA of Mexico.

It is also imperative to stress that scientific research is scarce on the social aspect of the problems present in NPA and community participation. Thus, it is imperative that more research be carried out to delve into these issues. This is because the

Table 24.8 Recommended research for the three NPA that lack management programs

NPA	Specific research recommendation
Molino de las Flores National Park	Social and environmental impacts of tourism and urban areas in the region, both of influence, like, no.
Cerro de la Estrella National Park	Social and environmental impacts of urban settlements
Lomas de Padierna National Park	Social and environmental impacts of urban settlements
Biosphere Reserve Ria Celestun	Social and environmental impacts of ecotourism
	Sociocultural impacts from ecotourism
	Socio-environmental and economic for the capture of "sea cucumber" and other species in closed impacts

Source: Constructed by authors

relationship between local communities, the use of natural resources, and social and economic systems cannot be ignored, especially regarding the social context of environmental problems (Martínez Alier and Jordi Roca 2013). Social context ultimately contributes to the identification of elements to consider in the design of environmental public policies focused on NPA, to ensure the achievement of sustainable development. The fact is that NPA regulations should be specific, inclusive, and contemplate "the diversity of opinions and rights of local communities ... ..." (Desmet 2014).

As for community participation, researchers such as Sosa et al. (2012) emphasize and exemplify that conflicts between communities and administrators are derived from lack of involvement of the local inhabitants in the planning and decision-making regulations of NPA. Public policies aimed at NPA must include community participation in decision-making, in order to link the population with their sustainable development.

It should be noted that the recommendations must be particular to each specific NPA, as derived from their precise contexts (ecosystem, economic, social, etc.). For instance, in Table 24.8, we offer specific research suggestions to be developed according to their particular circumstances.

24.6 Final Considerations

Since its inception, the administration and management of NPA in Mexico have been hampered due to the management of the diversity of its ecosystems and biological elements, because that circumstance impels a large investment of financial, human, and legal resources to integrate into a single scheme marine, coastal, and forest areas. This continues to defy the role of the National Commission of Natural Protected Areas (CONANP) (González Ocampo et al. 2014).

It is necessary to emphasize that even if at present, with so many tools for managing and organizing data, information, statistics, cartography, and criteria to be observed in the creation of NPA, it is urgent to continue the generation of knowledge through scientific research in them. Scientific research contributes to the strengthening and improving NPA. In short, the development of research with the purpose of identifying those outstanding issues that remain on the agenda of NPA contributes to the achievement of sustainable development in these areas.

The conservation of natural resources should be directed to observe the ecological, economic, and social for each NPA in particular contexts. However, there are several general recommendations: (a) the increase in financial resources for NPA, to ensure aspects such as monitoring of natural resources by governments and promote community participation; (b) training of human resources in the field, to disseminate the regulations to be observed in NPA, as the rules contained in management programs; (c) identifying those areas in and around NPA susceptible to socio-environmental impacts and in the already impacted to direct their efforts to ecological restoration (Pinkus et al. 2014); (d) increased budgetary allocation to CONANP for the labor incorporation of more personnel and organizational structure for surveillance work (park rangers); and (e) increase the state, municipal, private, and community administration, monitoring, and development of projects, in addition to just federal resources (Barrasa García 2012). However, all projects within a NPA must be compatible with the NPA primary mandate, that is, to conserve and sustain the ecological landscape, and it should be above any economic considerations.

It is necessary to emphasize the importance of promoting community participation, because involving local inhabitants in offering alternative livelihoods and desirable income, not only through exclusive promotion of use restrictions natural resources, sustainable development achieved in NPA. Also, it must be stressed that the multidisciplinary and multi-institutional scientific research related to sustainable use of natural resources, and all the updated information generated in NPA integration, is required in order to support the efforts of the CONANP.

The promotion and creation of opportunities for the development of scientific research requires coordination with research institutions and universities in order to generate knowledge that is useful for this goal. This knowledge provided by scientific research must be translated into technological and human capital to develop a better perception of the problems and needs to be resolved by the sustainable appropriation of the bio-cultural heritage, contributing to the conservation of NPA in the country.

The importance of scientific research in NPA stresses the actions required for the management and administration of these zones. It must be the basis for the design of public policies that guarantee the achievement of sustainable development in NPA. This is the final goal of the National Network of Protected Natural Areas (RENANP).

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