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Mexican Fauna in the Anthropocene

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Foreword

The Anthropocene is known as the geological epoch whose main characteristics of change are the results of human activity, from the origin of agriculture to the present day, and we do not know for how much longer this perturbation can no longer be sustainable for the human race. It is a time marked by technological advances that have generated huge imbalances in ecosystems, fragmenting, polluting, and destroying them. Human intelligence and its capacity to modify the environment are outstanding, but this capacity has not been accompanied by an awareness of the long-term consequences of these modifications. In the same way that we build cities, we annihilate natural spaces and extirpate plants and animals. We have polluted the oceans, cleared much of our forests, caused faunal extinction (defaunation), and in general depleted the natural resources. All this started with apparently simple and innocuous actions by a very small human population a few thousand years ago, which has been accelerated in the last hundred years, putting all life on Earth at risk.

Some of the consequences are the drastic environmental imbalances in natural ecosystems, global warming, and the effects of pollution by agrochemicals, plastics, and microplastics. The present great threats to biodiversity include an increasing number of species in danger of extinction combined with the decline in the abundance of populations of many animals due to the loss of their habitats. This represents by some the sixth great mass extinction event of the planet. Significant decreases in abundance have been detected in many animal groups. Besides the well-known threats to large vertebrates, now even many small-sized fauna, such as insects and other arthropods, are recognized as threatened. Their reduction of populations causes important effects on ecosystem functions, such as pollination and the reduction of population control of pest species. Whole ecosystems are being threatened, such as coral reefs and tropical forests. Additionally, in marine ecosystems, decreases have been observed in useful species for man and for the maintenance of ecosystems, such as sharks and many fish species. For birds, losses of 30% in their abundance have been estimated in the last 50 years, and the impact on ecosystems is clearly significant but difficult to determine.

The present book has 27 chapters written by national and international authors examining the actual state, threats, and future of Mexican fauna in the face of the various and current ecological, social, and economic threats unique to the country. It presents not only a panorama of the present state and threats to distinct faunal taxonomic groups, but their associated ecosystems and processes associated with human impacts; a work that elucidates the details and magnitude of the problems and provides guidelines to carry out actions to reduce the consequences for the fauna of Mexico.

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Part I
Introduction

Chapter 1
The Mexican Fauna in the Anthropocene, Where Do We Go from Here?

Robert W. Jones, C. Patricia Ornelas-García, Rubén Pineda-López, and Fernando Álvarez

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1.1 Introduction

Several terms in the last decades have had a significant impact on the way we think and act, among these are biodiversity, climate change, sustainable development, mass extinction, conservation, and recycling. All of these, however, can be combined to define a new reality in the times that human development has reached every corner of our planet and provoked substantial changes in natural cycles and processes, which have been called the "Anthropocene". Some authors propose that the activities of man since the second half of the eighteenth century, at the onset of the industrial revolution, have produced changes at a planetary scale modifying the atmosphere's composition, transforming more than half of the land surface of the planet, creating accelerated species extinction rates, and even producing measurable

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changes in the geology of the planet (Dirzo et al. 2014; McCauley et al. 2015; Young et al. 2016).

Defining "Anthropocene" proves to be a very difficult task, since many angles have to be considered when one attempts to either develop or accept a definition. The construction of the term denotes that it refers to a geological epoch, with marked shifts in Earth's state (Lewis and Maslin 2015), with a specific biota and/or well-defined strata or rock series. It is believed that man's impact on the planet has left and will continue to leave for centuries to come, an indelible mark on the Earth's surface and atmosphere.

The notion of a global-scale human-induced change of the planet is not new; it has been around for some 150 years, since the Italian priest Antonio Stoppani in 1873 talked about the human impact on the Earth referring to it as the "Anthropozoic Era" (Lucchesi 2017). Subsequently, many other authors and thinkers have arrived at a similar idea, producing a variety of definitions and describing a wide array of impacts at very different scales. Several important modern revisions are now available for the interested reader (e.g., Oldfield et al. 2014; Lewis and Maslin 2015), amid hundreds of publications. The effect of having this variety of interpretations around the same idea has prevented the emergence of single concept of "Anthropocene," although they converge on the same idea that human activities have radically changed the Earth's surface and its biodiversity.

A second challenge that has arisen regarding the concept of Anthropocene is to establish its limits, primarily when were the first effects visible? As Lewis and Maslin (2015) discuss, several starting points are possible as the geological stratigraphic markers needed to indicate the transition between epochs is not clear. Another problem is that the limits of the Holocene, as the preceding epoch, would have to be revised to accommodate the new period. It seems clear that hundreds or thousands of years into the future, the impact of man on the Earth's surface will be readily recognizable; however, given the pace that events are occurring now, the onset of the new epoch remains under debate.

Despite the definition problems and temporal uncertainties, it appears unquestionable that a planetary change is occurring. The editors of the present volume, as zoologists, saw the need to present an overview of what has and could occur to the diverse fauna of Mexico. To achieve this goal, we have invited experts of different zoological groups to explore the state of the art in their fields and to present alternative disturbance scenarios on what this fast rate of change will mean for our current faunal diversity, their ecosystems, and processes. We think that this is a significantly important idea since Mexico harbors around 10% of the world's species and the fate of this important fraction of the biota will have wide-ranging consequences.

The definition of the Anthropocene used herein is that proposed by Smith and Zeder (2013). These authors place the onset of the Anthropocene at the Pleistocene-Holocene, approximately 11,000 to 9000 years B.P. and defined as "when evidence of significant human capacity for ecosystem engineering or niche construction behaviors first appear in the archeological record on a global scale." Their criteria are based principally on ecological variables and thus most easily relate to the factors and causes that significantly impact animal species and their communities.

Thus, the Anthropocene epoch used herein is an "early" Anthropocene concept and is considered coeval with the start of the Holocene, starting roughly 11,000 years B.P (Doughty 2010). This period is at the dawn of the origins of agriculture and the domestication of animals and plants worldwide. Ellis et al. (2021) considered that these technological developments together with other land transformation practices were already significantly shaping the Earth's biosphere at this time.

1.2 History of the Anthropocene in Mexico

An overview of major environmental periods of the Anthropocene in Mexico can be roughly divided into three periods. The first is development of agriculture and greater social organization and technology of human indigenous societies from 11,000 to 1600 B.P. In fact, human populations had established in the northeastern portion of Yucatan Peninsula by 13,500 B.P., where multiple remains have been discovered in flooded caves (Hubbe et al. 2020). And by at least by 8000 B.P., humans were already impacting the environment based on carbon accumulation in strata that suggests selective use of fire by humans as well as the presence of pollen grains of an early maize subspecies and other early cultivars that have been found in central, western Mexico (Zizumbo-Villarreal and Colunga-García 2010).

This initial period of land transformation was followed by the development of greater complexity of indigenous cultures and their impact of land transformations due to more intense agriculture practices, population growth, and urbanization of indigenous cultures, up to the Spanish colonization starting in the fifteen century. In a recent study, they detect at least seven ecoregions in Mexico densely occupied before the European arrival. Thus, regions correspond to two in the Yucatan Peninsula (Plain and Hills and Northwestern Plain of the Yucatan Peninsula) and five in Central and Southern Mexico (Interior depressions, Gulf of Mexico, Transversal Neo—Volcanic System, Mexican High Plateau, and Sierra Los Tuxtlas) (Gónzalez-Abraham et al. 2015).

Using the Olmec culture as a starting point around 1600 B.P., the subsequent period is marked by several indigenous cultures that thrived and greatly transformed the natural landscape, especially in the Yucatan Peninsula with the Maya, in the Central Valleys of Oaxaca with the Zapoteca and later in Central Mexico by the Aztec. The population size of these societies is controversial. Population estimates of Mexico at the time of European arrival are highly variable ranging from 3 to over 50 million (Koch et al. 2019), with intermediate estimates for Mexico based on a synthesis of various methods and models that are calculated at 17.2 million (Denevan 1992). To maintain such populations, even at the lower size estimates, as well as the evident social stratification of the various cultures, required efficient and large-scale agricultural practices. These included extensive water management systems, including canals and wetland raised plots ("*chinampas*"), as well as terracing of highlands and diverse agroforestry practices (Fedick 2010; Canuto et al. 2018). Crop diversity was high and as many as 500 food plants were probably used (Fedick 2010; Casas

et al. 2016). Despite the diversity and sophistication of agricultural practices, significant erosion of soils is evident from many sites (González-Arqueros et al. 2017; Anselmetti et al. 2007). Per capita land use estimates for the Americas are calculated at 1.04 ha with Mexican estimates of within this range of 0.57–1 ha based on the "*milpa*" land use system (Koch et al. 2019). These land use levels combined with population estimates indicate that a significant area of highland and tropical forests was modified or converted to croplands or fields during the last millennial.

Besides habitat alteration due to urbanization and agricultural activities, harvesting of wildlife for food was also practiced and an important part of the pre-Columbian diet of indigenous societies in central México and presumably elsewhere (Zizumbo-Villarreal et al. 2016). Besides their use as food, animals had important religious and ritual values (jaguar; Fig. 1.1). In Mexico, there is considerable evidence of the transport of animal for symbolic-religious purposes that lingered on in the Native American cultures after the conquest (Valadez 1994; De la Garza 1999; Olivier 1999). For example, animals were part of the tributes given to by subjugated tribes to the Aztecs and included terrestrial vertebrates, fish and even invertebrates such as centipedes, scorpions, arachnids, snails, and shells (Durán 1581 quoted by Haemig 1978; Moctezuma 1985; Olivier 1999). Besides the transport for tributes and religious purposes, indigenous societies domesticated various species including stingless bees, turkeys, Psittaciformes (parrots, parakeets, macaws), and song birds such as the mocking bird (Valadez 1999). In addition, upon the arrival of the conquistadores in Tenochtitlan (Mexico City), they reported finding extensive gardens and a zoo with "countless" animals exotic to the Aztec homeland (Ixtlilxochitl, cited in Haemig 1978, Blanco et al. 2009). According to Hernán Cortés's *Segunda Carta de Relación* (1522), in the zoo of the supreme leader, Moctezuma, there were 600 men dedicated exclusively to the care of the zoo animals, including veterinarians to care for the sick individuals. This transport and domestication of animals are factors that can explain anomalous distribution patterns of some species found in Latin America. For example, the Great-Tailed Grackle *Quiscalus mexicanus* ("*zante*" or "*teotlzanatl*") was brought by the

Fig. 1.1 A "cuauhxicalli" or basalt vessel from the Mexica culture in the form of a feline on display at the National Museum of Anthropology in Mexico City (Wikepedia.org)

emperor Ahuitzotl from the tropical regions of the Gulf Coast to the Mexico City Valley (Bernardino de Sahagún, in Haemig 1978). This species became established in the Valley and currently continues its expansion in North America, mainly in human-altered ecosystems (Wehtje 2003). Another example of pre-Hispanic translocation corresponds to the goodeid fish species *Allotoca catarinae*, whose translocation was associated with settlements of the P'urhépecha culture around 1900 years ago in the Lerma river basin in the Transversal Neo-Volcanic System (Corona-Santiago et al. 2015).

The second period began when the Spanish arrived in the sixteenth century. They did not find a pristine landscape with scattered human settlements, but entered a continent with a sizable population living in anthropized landscapes. One of the first and most devastating introductions that European colonization brought to Mexico was Old World human diseases. The impact of the epidemics on the indigenous populations wrought by the introduction of these European diseases was monumental. Approximately 90% of the indigenous population was estimated to have been lost in Mexico by 1650 (Koch et al. 2019). The enormous population loss also meant a large reduction in agricultural activity and land use leading to a marked regrowth of secondary vegetation (Dull et al. 2013; Koch et al. 2019). On a continental scale, this expansion of secondary growth and reforestation of previously agricultural lands throughout the Americas has been argued to have been on such a scale as to have resulted in a worldwide reduction in atmospheric CO_2 and subsequent global cooling (Dull et al. 2013; Koch et al. 2019). In Mexico, this means that the colonization by the Spanish beginning in the sixteenth century initiated within a newly transformed landscape with a greatly reduced and socially transformed indigenous populations.

Another change in land use brought by the Spanish was through the introduction of grazing domesticated animals including cattle, horses, donkeys, mules, goats, and sheep as well as barnyard animals such as chickens and pigs. Having few domesticated animals, these were readily adopted by the native populations. The Spaniards also brought new crops including wheat, barley, sugar, bananas, temperate fruits, and many vegetables, although maize, beans, and other native crops remained preferred food crops of the indigenous populace.

European livestock were so successful that by 1550, there were flocks of up to 300,000 sheep in parts of central Mexico. This phenomenon caused a food and clothing revolution for the indigenous populations, but also brought major conflicts with indigenous farmers due to overgrazing that caused severe soil erosion, especially in the Mezcal and Mixteca regions (García 1999). Following the initial boom in livestock farming, land use and occupation of the land were more clearly defined, and fences or stone walls were built that separated different land uses and spatially delimited pastures (García 1999).

Despite these changes in agriculture, ownership of land was heavily favored for the Spanish colonists. At first, land was not as important as labor, which was conscripted from indigenous inhabitants ("*encomienda"*) to favored Spanish colonists, who also received most of the land grants (Butzer 1992). As the "*encomienda"* system was gradually phased out, increasing numbers of land grants were given to

Spanish settlers for sheep and cattle raising which became the major source of rural income (Prem 1992). The Spanish crown initially respected indigenous community lands in the granting of land grants, but many previously indigenous occupied lands were often abandoned due to the continued epidemics which were usually acquired be Spanish settlers (Butzer 1992).

By the late colonial period, extensive degradation was evident in many Mexican ecosystems (Skopyk and Melville 2018). The causes for this degradation are debated and clearly multifactorial including the shift from indigenous land use practices to colonial Spanish agricultural land use, overgrazing (Fisher et al. 2003), climate change (Skopyk 2017), population settlement patterns (Fisher et al. 2003), and loss of forest cover (Street-Perrott et al. 1989), among others.

Following Mexican Independence in 1821, there was little change in the land use practices and increasing consolidation of ownership by Spanish descendants, with further land degradation. This was heightened during the dictatorship of Porfirio Díaz established in 1876, when land and water resources were monopolized for industrial production and haciendas were further consolidated (Schumacher et al. 2019). The growth of large "*haciendas"* lead to industrialization of agricultural practices and further loss of the more sustainable, biodiverse land practices used by indigenous peoples (Schumacher et al. 2019).

The final period starts with the Mexican Revolution and its change in land use, together with the industrialization of agricultural production, exponential population growth, and urbanization of Mexico, during the twentieth and twenty-first centuries. The unjust social, economic, and land tenure conditions that ignited the Mexican Revolution in 1910 resulted in sweeping land reform. The new laws established after the revolution allowed the State to convert the "*haciendas"* into communal land, or "*ejidos,"* a communal land tenure system similar to that used in pre-Hispanic times, which is a unique form of land ownership (Schumacher et al. 2019). An "*ejido"* is formed when land is granted to a group of individuals for their use, which in practice is divided into family parcels, over a portion of the land grant. Currently, slightly more than half of the surface of Mexico is in possession of "*ejidos"* or agrarian communities and includes mountains, extensive forests, arid regions and is often within national and state designated protected areas (Morett-Sánchez and Cosío-Ruiz 2017; Schumacher et al. 2019). As such, most ecosystems in Mexico are social property and are the primary source of livelihood for the "*ejiditarios."* The land use of "*ejidos"* is mainly dedicated to agricultural activities, including farming and livestock grazing, but also direct resource extraction including firewood, construction materials, and harvesting of wild plants and animals, among others (Flores-Rodríguez 2008; Morett-Sánchez and Cosío-Ruiz 2017; Schumacher et al. 2019). The "*ejidos"* and their rural Mexican areas, in general, are important regions of environmental heterogeneity formed by different crop lands, minimally managed ecosystems, areas of secondary vegetation, and remnants of natural vegetation (Fig. 1.2). Although these regions are often clearly disturbed, they can maintain significant biological diversity (Hiley et al. 2016; Blasio-Quintana and Pineda-López 2020; Cruz-Elizalde et al. 2022).

Fig. 1.2 Heterogeneous landscape of Ejido el Madroño, in municipality of Pinal de Amoles, Querétaro. In foreground, minimally managed and favored agaves and piñon pines in area also used for cattle grazing, with mixed oak-pine forest fragments in background including small, settlement clearings

However, although "*ejidos"* have been one of the most resilient communities of the world and have been adapted to a myriad of economic and societal changes, the living conditions of many of the "*ejiditarios"* have worsened during the twenty-first century (Barnes 2009; Morett-Sánchez and Cosío-Ruiz 2017; Schumacher et al. 2019). Importantly, legislatorial changes in 1998 permitted the ownership of "*ejidal"* property to being legally transformed to private property, resulting in massive growth of peri-urban areas around the urban cores of Mexican cities (Schumacher et al. 2019). These conditions and changes in rural Mexico have led to increasing migration of "*ejiditarios"* and the rural poor to large cities in search of factory jobs or migration to the USA and Canada (Morett-Sánchez and Cosío-Ruiz 2017). This together with continued population growth during the latter part of the twentieth century has resulted in an incessant increase in levels of urbanization (Fig. 1.3), continued deforestation, further industrialization of agricultural production with increasing environmental contamination and negative impacts of established and new exotic species (SEMARNAT 2016).

Despite that the Mexican territory has been modified by man for more than 4000 years (Somerville et al. 2021), and markedly so within the last 70 years, there are important positive accomplishments in environmental protection. Government environmental agencies have been created and evolved in various sectors including the Department of Environment and Natural Resources (Secretaría del Medio Ambiente y Recursos Naturales, SEMARNAT), under which is the National Commission of Natural Protected Areas (CONANP), and the National Commission for the Knowledge and Use of Biodiversidad (CONABIO), among other national, state, and local agencies. Important environmental laws were founded in 1988 in the General Law on Ecological Equilibrium and Environmental Protection (LGEEPA) which is enforced by the Federal Attorney for Environmental Protection (PROFEPA).

Currently, CONANP administers 183 federal natural protected areas (NPAs) accounting for 90,942,124 hectares in addition to 371 areas voluntarily destined for

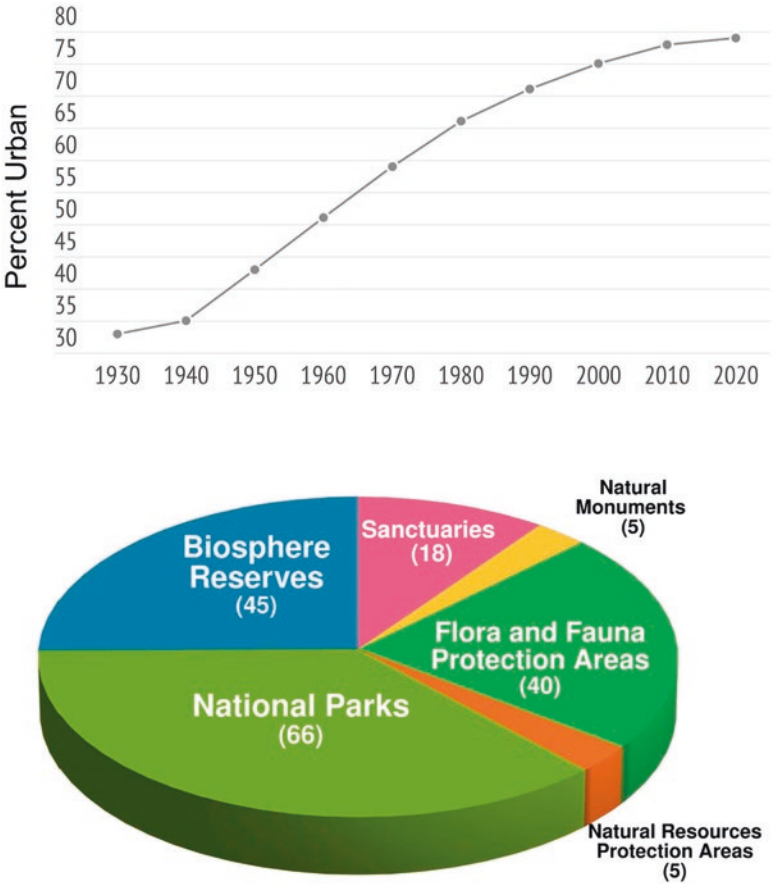

Fig. 1.3 Top. Growth of percent urban population growth in Mexico (INEGI, Censo de Población y Vivienda 2020); bottom. Number (parentheses) and types and numbers of protected areas in Mexico (CONANP 2022)

conservation, with a total area of 604,906 hectares (CONANP 2022). Of these areas, more than 95% were created after 1995 (Ocampo et al. 2014). Of the NPAs, 21,483,510 hectares correspond to terrestrial ecosystems, representing 10.93% of the national land area, whereas the protected marine surface comprises 69,458,613 hectares, corresponding to 22.05% of the national territory of marine waters (Fig. 1.3; CONANP 2022). Although these agencies and the protected areas suffer political, social, and economic challenges and despite the unremitting trends that continue through urbanization and habitat destruction as seen throughout the world, what is remarkable is that even today, the diversity of species Mexico, including its fauna, is still very high. However, as is articulated in the present volume, almost all faunal groups and the ecosystems that maintain them are imperiled.

1.3 Final Remarks

There appears to be a growing acceptance of the term Anthropocene by the scientific community and the general public. With this, the recognition that the physical and biological changes on the planet we are now experiencing are comparable to the other five major extinction events in geological time. This acceptance is evidenced by the creation of new scientific journals such as Anthropocene, The Anthropocene Review, Elementa: Science of the Anthropocene, Anthropocene Science, Anthropocene, among others, which have been created in the last 5 years to cope with an increasing number of studies on this topic. In the present volume, we use the term to focus the exploration of a wide range of topics related to the past and current conservation status of major faunal groups in Mexico and a prognosis of future challenges and the expanding threats inherent within the context of the unique physical, biological, and cultural aspects of the nation. We also hope to reach a broad audience beyond academics to promote ideas and awareness of the apparently, irreversible trajectory the world has embarked and in particular, in reference to the unique and diverse fauna of Mexico. As the mounting evidence of negative impacts on biodiversity and invaluable ecosystem functions continues to accumulate in the different realms, the question becomes, Where do we go from here? Our discussion as a society will have to shift from the efforts to confirm the existence of the Anthropocene to a more proactive attitude, in which we incorporate understanding of local, regional, and global processes of the human impacts threatening biodiversity and on the associated ecosystem services in order to formulate viable strategies to mitigate the consequences.

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Part II
Faunal Groups

Chapter 2
The Fauna of Arachnids in the Anthropocene of Mexico

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Contents

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