

Article

## Is Sustainability Possible in Protected Areas in Mexico? Deer as an Example of a Renewable Resource

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**Abstract:** In 2000, Mexico's National Commission of Protected Areas (CONANP) was created to encourage the protection, management and restoration of natural and cultural resources and their conservation. Protected areas were recently increased by more than 3 million hectares, for a current total of more than 25 million hectares, corresponding to 174 protected areas that cover 12.90% of the country's surface area. The information obtained by research helps us understand both biodiversity and ecological processes, as well as the social and economic phenomena that influence the use of ecosystems. In Mexico there are four species of deer: white-tailed deer, mule deer, red brocket and brown brocket. These ungulates have been an important part of the diet of indigenous people and rural communities, and represent an important resource for sport and trophy hunting. We found the best deer populations in protected areas; these can therefore maintain the gene pool and serve as source populations for other areas. These populations are also useful from a research perspective. People living in some protected areas continue to use natural resources such as deer, and also receive economic inputs to develop ecotourism programs, and support from the government for the environmental services derived from conserving biodiversity.

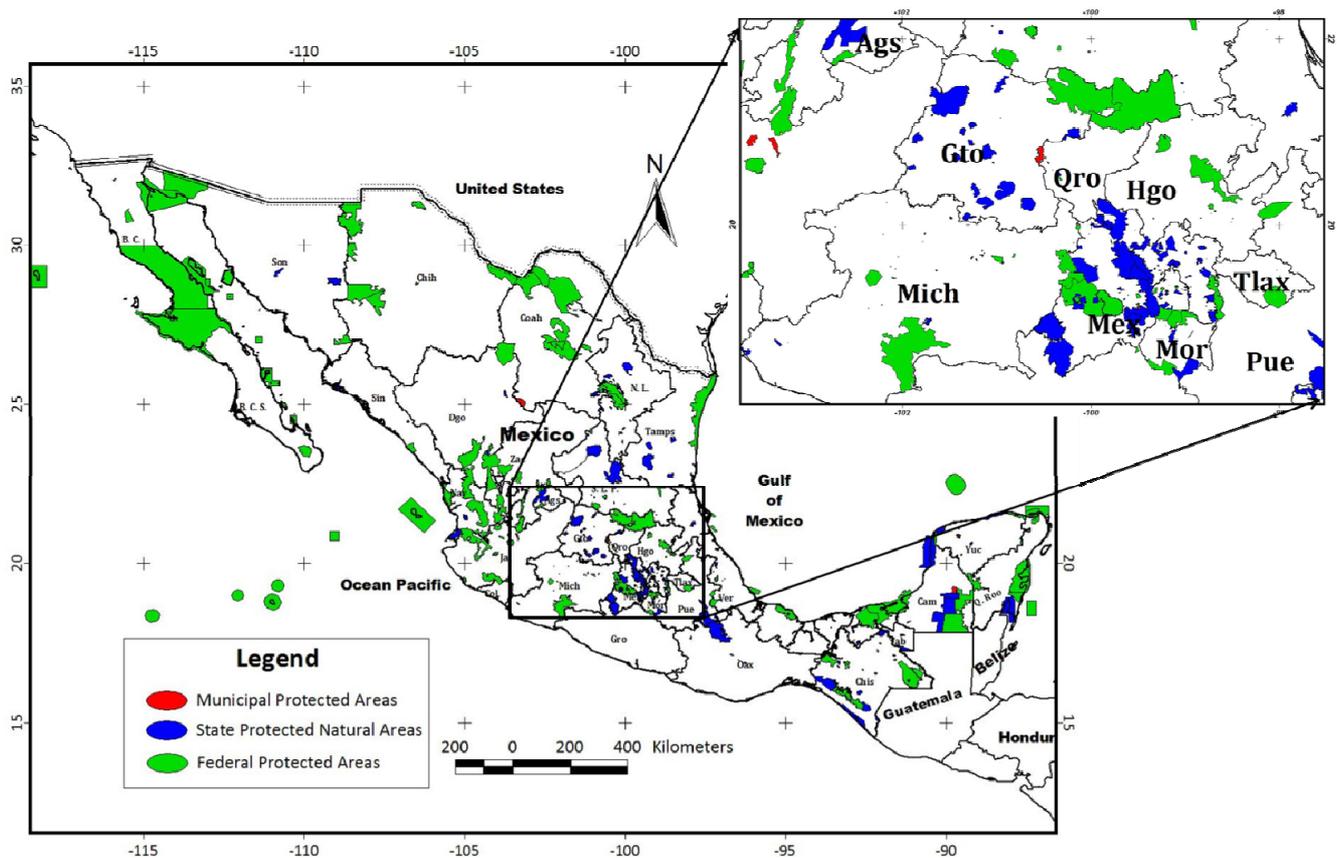
**Keywords:** deer; hunting; biodiversity; population; Mexico; CONANP

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## 1. Introduction

Protected areas in Mexico are managed by the National Commission for Protected Natural Areas (*Comisión Nacional de Áreas Naturales Protegidas*; CONANP), which was created in 2000, and has the following objectives: 1) Understand and make decisions based on knowledge; 2) Assess biodiversity and ecosystems and promote a culture of conservation through participation; 3) Regulate, promote and carry out conservation, with the ultimate aim of sustainable development based on knowledge generated about conservation. One of the relevant premises: “To achieve sustainability it is necessary to involve society in its entirety. The conservationist culture seeks to properly assess all aspects of ecosystems and biodiversity and is based on education (formal and informal), training, participation and the use of strategic communication: since the culture of conservation is expected to result in people changing their behavior. These changes, which are already taking place, may be gradual but they are still urgent considering the magnitude of the environmental crisis”. This is summarized on CONANP’s webpage [1] as follows: “Conservation is simply a way to address the sustainability of the human species from the point of view of ecosystems and their biodiversity and to commit as individuals and as a society to attaining said sustainability.”

**Figure 1.** Protected Natural Areas in Mexico



Recently, there has been a substantial increase of more than 3 million hectares in the protected areas of Mexico. The total is now more than 25 million hectares and this represents 12.9% of the national territory, located in 174 protected areas (Figure 1;[1]). In Mexico, research on deer in the Protected Natural Areas (PNA) has produced a very important body of knowledge [2] that has increased what we

know about biodiversity and the ecological processes that occur within the protected areas, and to understand the social and economic phenomena that affect the way ecosystems are used. Here the conservation and use of deer as one of the important fauna resources in Mexico is presented as an example. Deer represent a source of income for many inhabitants, and protected areas are important for research that will lead to their sustainable use and therefore their conservation [2–3]. There are four native species of deer in Mexico: white-tailed deer, *Odocoileus virginianus* (Zimmermann, 1780), mule deer, *O. hemionus* (Rafinesque, 1817), red brocket deer, *Mazama temama* (Kerr, 1792) and brown brocket deer, *M. pandora* (Merriam, 1901). Since pre-Colonial times these ungulates have formed an important part of the food base for different indigenous groups and continue to be a notable component of the diet in rural communities. In Latin America subsistence hunting is an important activity that provides a substantial proportion of high quality protein in the diets of rural people [4–5], and deer also represent important wild game for sport hunters.

Mexico has a “Management Plan for the White-Tailed Deer of Temperate and Tropical Regions”, which is used to set up the Management Units for the Conservation of Wildlife (known as UMAs in Spanish: *Unidad de Manejo para la Conservación de la Vida Silvestre*) that are overseen by SEMARNAT [6]. UMAs allow for the use of wildlife and their products and their legal commercialization. This scheme promotes the conservation and rational use of Mexico’s natural resources [6]. UMAs represent an entirely new conservation paradigm with the potential to increase the direct benefits that biodiversity provides to people, thereby creating new incentives for conservation efforts [7]. Starting in 1997 when UMAs came into being along with the decree of the General Wildlife Law, strategies for wildlife conservation and management were made explicitly clear. Certain *ejidos* (*i.e.*, communal land under the stewardship of rural inhabitants and used for agricultural activities), indigenous communities and small landowners have reorganized their efforts and finances in order to manage and make use of wildlife in nearly 26 million ha [8]. Some of the UMAs that are located in *ejidos* form part of PNAs, particularly in southeastern Mexico.

The objective of this study is to examine the role of the Protected Natural Areas of Mexico in generating information about deer populations and whether the use of deer populations managed in UMAs is feasible. To this end, we analyzed the areas where studies have been done, including the data bases from publications [2,3], the size of the PNAs and the proportion of the range that is under protection for each of the four deer species, in addition to the ways deer are used in different regions of Mexico.

## 2. Results and Discussion

### 2.1. Protected Areas Where Research Has Been Done

Numerous studies have been done on the native deer species of Mexico and the characteristic types of vegetation in the areas where they are found (Table 1). Most of the protected areas have white-tailed deer, whose distribution covers almost the entire country, with the exception of the Baja California Peninsula. It is, undoubtedly, the most important game species [9], particularly in northern Mexico. There, UMAs have been very successful. These units, operating under the auspices of the federal government, provide the means for flora and fauna to be used in a rational manner.

**Table 1.** Description of the protected natural areas in Mexico [1] and the deer species that inhabit them [3].

Protected Area and the State in Mexico Where It Is Located	Area (ha)	Vegetation Type	Deer Species Studied
<b>Biosphere Reserves</b>			
La Michilía, Durango	9325	Mixed pine-oak temperate forest	White-tailed deer ( <i>Odocoileus virginianus</i> )
Manantlán, Jalisco	139,577	Mixed pine-oak temperate forest, Cloud forest	White-tailed deer ( <i>Odocoileus virginianus</i> )
Chamela-Cuixmala, Jalisco	13,142	Tropical deciduous forest	White-tailed deer ( <i>Odocoileus virginianus</i> )
Sierra Gorda, Querétaro	383,567	Temperate forest, Oak forest, Tropical deciduous forest	White-tailed deer ( <i>Odocoileus virginianus</i> ) and red brocket ( <i>Mazama temama</i> )
Sierra de Huautla, Morelos	59,031	Tropical deciduous forest	White-tailed deer ( <i>Odocoileus virginianus</i> )
Sian Ka'an, Quintana Roo	528,148	Semi-evergreen tropical forest	White-tailed deer ( <i>Odocoileus virginianus</i> )
Montes Azules, Chiapas	331,200	Tropical rainforest	White-tailed deer ( <i>Odocoileus virginianus</i> )
Calakmul, Campeche	723,185	Tropical deciduous forest	White-tailed deer ( <i>Odocoileus virginianus</i> ), red brocket ( <i>Mazama temama</i> ) and temazate café ( <i>Mazama pandora</i> )
Los Tuxtlas, Veracruz	155,122	Tropical rainforest	White-tailed deer ( <i>Odocoileus virginianus</i> ) and red brocket ( <i>Mazama temama</i> )
Tehuacán-Cuicatlán, Puebla-Oaxaca	490,186	Tropical deciduous forest, Oak forest, Desert scrub	White-tailed deer ( <i>Odocoileus virginianus</i> ) and red brocket ( <i>Mazama temama</i> )
Sierra de La Laguna, Baja California Sur	112,437	Temperate pine-oak forest, Oak forest	Mule deer ( <i>Odocoileus hemionus</i> )
Mapimí, Durango-Chihuahua-Coahuila	342,388	Chihuahuan Desert scrub	Mule deer ( <i>Odocoileus hemionus</i> )
Isla Cedros, Baja California	34,700	Coniferous forest and desert scrub	Mule deer ( <i>Odocoileus hemionus</i> )
Isla Tiburón, Sonora	120,800	Sonoran Desert scrub	Mule deer ( <i>Odocoileus hemionus</i> )

Table 1. Cont.

Protected Area and the State in Mexico Where It Is Located	Area (ha)	Vegetation Type	Deer Species Studied
<b>National and State Parks</b>			
La Primavera, Jalisco	36,229	Temperate pine-oak forest	White-tailed deer ( <i>Odocoileus virginianus</i> )
Desierto de Los Leones, Federal District	1866	Temperate forest	White-tailed deer ( <i>Odocoileus virginianus</i> )
La Sierra State Park, Tabasco	15,113	Tropical rainforest	White-tailed deer ( <i>Odocoileus virginianus</i> ) and red brocket ( <i>Mazama temama</i> )
Gral. Lázaro Cárdenas State Park, Puebla	700	Oak forest, Thorny scrub	White-tailed deer ( <i>Odocoileus virginianus</i> )
Protection area for flora and fauna: The Chichinautzin Biological Corridor, Morelos	37,302	Temperate forest	White-tailed deer ( <i>Odocoileus virginianus</i> )
<b>Private Reserve</b>			
El Edén, Quintana Roo	1492	Semi-evergreen tropical forest, Secondary vegetation	White-tailed deer ( <i>Odocoileus virginianus</i> ), red brocket ( <i>Mazama temama</i> ) and brown brocket ( <i>Mazama pandora</i> )

Of the research studies done on white-tailed deer (327 in total), 40% was done in PNAs, of those on mule deer 69% was done in PNAs, and of the 40 studies on brockets all were done in PNAs [3]. A number of the PNAs fall within the distribution ranges of the four cervid species; however the total protected area only represents 9.5% of the entire combined distribution of the four species (Table 2). Brown brocket is the species about which the least is known (Table 2).

**Table 2.** Distribution area and number of Protected Natural Areas (PNAs) within the distribution of the four cervids native to Mexico.

Species	Distribution Area (km <sup>2</sup> )	Number of PNAs in the Deer's Distribution Range	Protected Area (km <sup>2</sup> )	Percentage of the Deer's Distribution Area that Is Protected
<i>Odocoileus virginianus</i>	1,763,490.79	117	107,453.07	6.1%
<i>Odocoileus hemionus</i>	560,957.50	18	84,994.25	15.2%
<i>Mazama temama</i>	419,658.67	40	53,072.24	12.6%
<i>Mazama pandora</i>	130,089.79	10	26,301.14	20.2%
Totals	2,874,196.75	185	271,820.70	9.5%

### 2.1.1. Distribution Area of Deer Species and Proportions of Those Areas Under Protection

At least 117 PNAs fall within the white-tailed deer's distribution, for a legally protected area of approximately 107,453 km<sup>2</sup>, or 6% of this species' historical distribution [3]. Within the historical distribution of mule deer in Baja California and the northwestern part of the country there are only 18 PNAs, with an area of 85,000 km<sup>2</sup> protected by legal decree that represents 15.2% of its distribution. The red brocket is found in the states on the Gulf of Mexico and in southeastern Mexico.

There are 40 PNAs in its distribution range, with at least 53,072 km<sup>2</sup> protected by decree, representing 12.6% of its historical distribution. Brown brocket has the most limited distribution and is only found on the Yucatan Peninsula, with 20.2% of its distribution in protected areas [3]. As such, the latter is the least threatened species because a substantial part of its habitat is under conservation. An analysis of each species of cervid reveals the following:

**White-tailed deer:** Within its distribution area (1,763,491 km<sup>2</sup>; Table 2), research has been done in 16 Protected Natural Areas (11 of which are Biosphere Reserves which protect large tracts of land), with the following ecosystems: mixed temperate forest, deciduous tropical forest, semi-evergreen tropical forest and tropical rainforest. Of the 14 subspecies that are found in Mexico, the following seven have been studied: *O. v. couesi*, *O. v. sinaloae*, *O. v. mexicanus*, *O. v. yucatanensis*, *O. v. nelsoni*, *O. v. thomasi*, and *O. v. veraecrucis*. There is research on population dynamics, feeding habits, habitat use, competition with domesticated species, and behavioral ecology, among other topics [2,3]. Most of the studies have reported that the density of the deer populations is acceptable and that it is possible to make sustainable use of them, as long as the rate of use is properly controlled and habitat is conserved to ensure that the needs of the species are met.

**Mule deer:** The area of distribution for this species is the northwest of the country, including all of the Baja California Peninsula, and covers 560,958 km<sup>2</sup>. The populations have been studied in four protected areas: the Sierra de La Laguna Biosphere Reserve, in Baja California Sur (*O. h. peninsulae*), in the region with mixed pine-oak forests and in the Mapimí Biosphere Reserve in Durango (*O. h. crooki*) characterized by the scrub of the Chihuahuan Desert, and on two islands, Cedros Island (*O. h. cerrocensis*) and subspecies *O. h. sheldoni* on Tiburón Island (Table I). Studies of this species have also focused on population density, habitat use, metapopulation dynamics, risk factors, competition with wild pigs and domesticated species such as cattle, and the effect of predators such as puma [2,3].

**Brocket deer:** Of the two species of *Mazama*, *M. temama* has been studied the most. Its historical distribution area covers 419,659 km<sup>2</sup>, and studies on it have only been done in four Biosphere Reserves: Calakmul, in Campeche, Montes Azules in Chiapas, Los Tuxtlas in Veracruz and recently in La Sierra Gorda, Queretaro. Studies have also been done in El Eden, a private ecological reserve, in Quintana Roo and in a state reserve, the La Sierra State Park, in Tabasco (Table I). Population estimates have been made only using deer signs (tracks, scat, antler rubs, etc.) and there have been several studies examining the impact of subsistence hunting and habitat transformation on its populations [10–13].

For *M. pandora*, recently described [14], the reported distribution is only 31% of the area of its sympatric species *M. temama*, covering 130,089 km<sup>2</sup>. This is the smallest distribution area of all the Mexican cervids. Research on this species is scant and has only been done in the Calakmul Biosphere Reserve in Campeche and in the El Eden Ecological Reserve in Quintana Roo [2,3] (Table 1).

### 2.1.2. The Use of Deer

The use of deer from the UMAs has been successful in the northern states of Mexico: Tamaulipas, Coahuila, Chihuahua, Sinaloa, Sonora, the Californias, Zacatecas, Durango and Nuevo Leon.

Several characteristics of the UMAs that are in the north of the country make the use of deer highly feasible and sustainable in economic terms [9]:

1. Size. Most of the hunting ranches that have been transformed into UMAs occupy very large tracts of land.
2. The owners have extensive hunting experience, a solid group of contacts and commercialization channels owing to the practice of raising livestock in addition to managing the UMA for hunting.
3. The majority of the UMAs are located near Mexico's border with the USA, where there are wealthy hunters.

In contrast, UMAs in central and southeastern Mexico face very different conditions; so different that it has been argued that the UMAs in southeastern Mexico have had a negative impact on wildlife conservation and on rural development in the impoverished communities where they have been set up [13]. In the central and southern states of the country the effectiveness of the UMAs is nowhere near that of the northern states. This can be explained by three factors that, at least in part, explain the difficulties in applying this wildlife strategy in southeastern Mexico. First, there is extensive ecosystem fragmentation in this region and—with the exception of the interior of the largest PNAs of the Mexican tropics—this has given rise to a landscape of patches and relicts for which planning and adaptive management represent a formidable challenge. Also, most of the land is *ejidos* and communal, and its extreme fragmentation makes it exceedingly difficult to find sites to set up and operate large UMAs that can be managed by a single owner. Finally, poverty in the communities and *ejidos* where the land is located make it virtually impossible to conceive of rural property owners becoming prosperous businessmen, without first implementing a training program and other types of support to assist them in the appropriation of resources that may eventually be profitable [8]. In the southeast, *ejidos* and small properties are usually less than 1000 ha in area and their owners are rarely willing to use all of their land to start up an UMA. Additionally, the areas that might be used for UMAs are, at least individually, too small to manage sustainable populations of the wildlife that is characteristic of the different ecosystems in the region.

During 2008–2009 for the use of white-tailed deer, SEMARNAT (the Mexican Ministry of the Environment) issued 15,398 permits (one permit authorizes the holder to take one male deer) to 1285 UMAs in 18 states, including the different subspecies (10 of the 14 subspecies are recorded for Mexico). For *O. v. texanus*, the most highly valued subspecies for hunting, 11,920 permits were issued in 900 UMAs in six states, though the distribution of this subspecies only covers 4 states: Tamaulipas, Nuevo Leon, Coahuila and Chihuahua [15]. However, it is not known how many of the permits were actually used. According to Mexico's wildlife law, only adult males can be hunted and only during the hunting season from November to February, though the females can be captured alive and sold to repopulate other UMAs. Subsistence hunting is not regulated and occurs throughout the year, with both sexes and animals of all ages hunted. The number of permits issued to each UMA depends on the population size which is estimated annually; permits allow for less than 10% of the estimated number of males to be hunted [9]. This has allowed for the recovery of deer populations where poaching had previously decimated them.

In Mexico deer population densities are highly variable, from 1–2 (central and southern Mexico) to 20 deer/km<sup>2</sup> (some reserves and UMAs in northern Mexico; see details in Gallina *et al.* [16]), although many populations have around or less than 10 deer/km<sup>2</sup>. Unlike the USA, there have not yet been any known ecological impacts from overpopulation. Under the UMA scheme the habitat is protected and wildlife can be conserved and used; this approach has been particularly successful in northern Mexico.

In the PNAs of southeastern Mexico, especially where there is subsistence hunting, the sustainability of the deer harvest can be determined as long as the characteristics of the populations and their habitats are taken into account. Bodmer [17] presented a model for evaluating the sustainability of hunting in the Neotropics that incorporated a number of population variables. He called it a unified model because it incorporates an analysis of stock recruitment. For many wildlife species Robinson and Redford [18] assume that 60% of the estimated carrying capacity (K) is the density attained for populations that are not hunted. This method has been used in the tropics wherever there is subsistence hunting because of the complications involved in calculating more accurate values for carrying capacity using more robust methods. This approach uses empirical information to examine whether species are overhunted or if they are vulnerable to overhunting. It is based on population parameters and hunting pressure. So, if the size of the base population of deer is greater than 60% of K then the harvest can be considered sustainable in the long term [17]. In the Tamshiyacu-Tahuayo Communal Reserve in the highlands of the Peruvian Amazon, deer populations were found to be at 75 and 87% of their K, so they can be sustainably harvested. In conjunction with those studies, for the PNAs of southeastern Mexico, the research of Reyna-Hurtado and Tanner [11] in the Calakmul Reserve—one of the last remaining pristine places in Meso-America—confirms that brocket deer can tolerate the current levels of hunting pressure and some degree of forest fragmentation, though their viability may depend on their survival as a metapopulation. In that study, the relative abundance of white-tailed deer was significantly greater in hunted areas than in the non-hunted areas, and there were no significant differences in brocket deer (measured by the track encounter rate) between hunted and non-hunted areas, so they concluded that these deer species are resistant to hunting pressure. Hunting may have important secondary effects on the persistence of wildlife populations, such as influencing the time and the manner in which an animal uses different habitat types. Studies by Naranjo *et al.* [10] and Naranjo and Bodmer [19] suggest that the populations of ungulates are in good shape in sites where there is no hunting or where hunting pressure is low, such as in the Montes Azules Biosphere Reserve. The situation is different though where hunting is continual, such as in the Lacandona Forest where, together with habitat transformation and fragmentation, hunting has decimated the populations of some of the most vulnerable species. Therefore, differential species vulnerability, catchment size, and consumer population size are important factors in determining sustainability [20].

In Mexico, there has been an exponential increase in the number of UMAs set up with a total of 11,839 units covering 37.35 million ha as of July 2012 [21]. Even though the first UMAs were created in 1997, very few have been evaluated, making it difficult to analyze the impact they have had on wildlife conservation [7,13,22–24]. This is important because UMAs, together with Environmental Impact Assessments and Protected Natural Areas, are the main instruments of biodiversity conservation in the country.

### 3. Conclusions

The quantity and high quality of biological research taking place in the Protected Natural Areas in Mexico, particularly the Biosphere Reserves, demonstrates that these areas are meeting one of their fundamental objectives; that of serving as sites for generating knowledge for conservation, in addition to being areas where the conservation of ecosystems is a priority. Their success to date reinforces their importance and ensures their continued existence over time, regulating the use of resources. The PNAs which have been key to generating information about deer in Mexico and have doubtless had an impact on defining management strategies for deer populations in UMAs so that they can be a sustainable resource, especially outside of the protected areas but also within protected areas (particularly in southeastern Mexico) where subsistence hunting improves the quality of life in the hunters' communities. The deer populations in the PNAs can certainly be considered source populations under the concept of metapopulations, and can be used to repopulate other areas where populations have been adversely affected and where there is still suitable habitat available for their survival.

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### Conflict of Interest

The author declares that there are no conflicts of interest.

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