Research Article

Evaluation of Natural Conservation Areas and Wildlife Management Units to Support Minimum Viable Populations of White-Tailed Deer in Mexico

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Abstract

In Mexico, wildlife conservation and management is officially based on two schemes: Natural Protected Areas (ANP, in Spanish), and Wildlife Conservation, Management and Sustainable Utilization Units (UMA). In this paper we evaluated whether these areas satisfy a minimum critical area (MCA) to support theoretical values of minimum viable population (MVP) of white-tailed deer, *Odocoileus virginianus*. MCAs were estimated using a model based on population density values from 1 to 30 deer/km^2. MCA increased as density decreased. Results suggest an MCA of 1,667 to 50,000 ha to support an MVP of 500 deer, or 16,670 to 500,000 ha for long-term viability of 5,000 deer, depending on regional deer density. Biosphere Reserves, Protection Areas of Flora and Fauna, and Protection Areas of Natural Resources satisfy MCA requirements better than other ANP categories. In general, almost no UMA cover MCA. Geographic distribution of larger ANP and UMA are biased towards the North and Southeast of Mexico. We also evaluated the proposal of Priority Terrestrial Regions (RTP), and found that these areas could better satisfy MCA requirements; particularly, RTP could complement the need for reserves in the central part of the country. Selected study cases were used to illustrate the utility of this model to evaluate specific locations to know if MCA requirements are satisfied to support MVP of this deer. We suggest a regional network system of conservation reserves and wildlife management units integrating ANP, UMA, and RTP at regional scale, through source-sink and archipelago reserve models.

Key words: white-tailed deer, conservation, management, population viability, minimum critical area, source-sink reserves, archipelagos reserves.

Resumen

En México, la conservación y el manejo de la fauna silvestre está legalmente sustentado en dos esquemas: Áreas Naturales Protegidas (ANP), y Unidad de Manejo y Aprovechamiento para la Conservación de la Vida Silvestre (UMA). En este trabajo evaluamos estas áreas para conocer si tienen un tamaño de área mínima crítica (MCA) para sustentar poblaciones mínimas viables (MVP) de venado cola blanca, *Odocoileus virginianus*. El MCA fue estimado empleando un modelo basado en un gradiente de densidad poblacional de 1 a 30 venados/km^2. El MCA aumenta conforme disminuye la densidad poblacional. Los resultados sugieren que se requieren MCA entre 1667 y 50,000 ha para sostener MVA de 500 venados, y de 16,670 a 500,000 ha para sostener poblaciones viables a largo plazo de 5,000 venados. La evaluación indica que las Reservas de la Biosfera, Áreas de protección de Recursos Naturales, y Áreas de Protección de Flora y Fauna, son las ANP que mejor cumplen con el MCA. En general, las UMA no satisfacen el MCA. La distribución geográfica de las ANP y UMA de mayor tamaño está sesgada hacia el Norte y Sureste del país. Adicionalmente, también evaluamos las áreas propuestas como Regiones Terrestres Prioritarias (RTP) y encontramos que éstas satisfacen bien el MCA, y podrían complementar notoriamente la necesidad de áreas extensas en el centro del país. Seleccionamos varios estudios como casos para ilustrar la utilidad de este modelo para evaluar sitios específicos para conocer si satisfacen los requerimientos de MCA para sostener MVP de este venado. Sugerimos la necesidad de crear sistemas de redes de conservación y manejo incorporando ANP, RTP y UMA en una misma región considerando modelos de tipo fuente-sumidero y/o redes de reserva tipo archipiélagos.

Palabras clave: venado cola blanca, áreas protegidas, unidades de manejo y conservación, poblaciones viables, área mínima crítica.

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Introduction

Estimating minimum viable population (MVP) has practical applications in conservation, management, and species recovery programs, and allows for further assessment of species habitat requirements and for determination of the size of reserves and population corridors [1-3]. An MVP is an estimate of the number of individuals required for a high probability of survival of the population over a given period of time [4]. More specifically, MVP is the smallest possible size at which a biological population can exist without facing extinction from natural disasters or demographic, environmental, or genetic stochasticity. For example, two definitions of MVP are: "> 95% probability of persistence over 100 years" and "a > 99% probability of persistence for 40 generations" [3,4].

Efforts to define, model, and predict MVP have been a major focus in conservation biology research [5]. A common procedure to estimate MVP is using population viability analyses (PVA), where populations are modeled and future population dynamics are projected [6]. In general, PVA is the study of all factors that may cause a species to go extinct [7]. Specifically, PVA could be defined as the use of data in an analytical or simulation model to calculate the risk of extinction after some specified period of time [8]. However, there are significant problems with the use of any hard numbers in estimating MVP because there is, as yet, no synergistic model that takes genetic, demographic, and environmental uncertainties and catastrophe into account [5].

Some authors argue that it is more important to estimate the effective population (Ne) size than to define MVP [9]. Franklin [9] proposed the 50/500 rule used by conservation practitioners, whereby an Ne of 50 is required to prevent an unacceptable rate of inbreeding, while a long-term Ne of 500 is required to ensure overall genetic variability. From a population genetics perspective, estimations of Ne are 50 individuals to avoid inbreeding depression, 12 to 1,000 to avoid the accumulation of deleterious mutations, and 500-5,000 to retain evolutionary potential [10]. Given that the average Ne/N ratio is roughly 0.10, these rules of thumb translate to census sizes of 500 to 5,000 individuals [10]. Soulé [1] considered that the MVP would often be a population size of 10,000 to permit long-term demographic persistence and to satisfy genetic considerations. Reed *et al.* [7] estimated that in order to ensure long-term persistence of vertebrate populations, sufficient habitat must be conserved to allow for approximately 7,000 breeding adults. Recently, Traill *et al.* [3] using a meta-analysis of 30 years of published estimates of MVP, covering 141 sources and 212 species, derive a cross-species distribution of MVP with a median of 4,162 individuals (95% CI = 3,577-5,129).

Protecting species requires sufficient habitat to support the MVP over time [e.g., 5, 11-14]. Thus, it is important to estimate the minimum area requirement or minimum critical area (MCA). There have been different approaches to estimating MCA, such as incorporating information on the home range and dispersal distances of mammals [15], their density [2], or the relationship between habitat area and population extinction [14]. The characterizing of MCA in patch networks, functional connectivity across habitat patches, and metapopulation dynamics for a key species will allow the identification of landscape patches key to the viability of target species, and thus the patches most critical for the conservation of viable populations [12]. Therefore, the identification of those patches that meet the MCA to sustain MVP could help to design conservation networks at regional scale. This possible scenario is similar to the "reserve networks" or "archipelago reserves," which is a type of protection in some regions where beta diversity is the dominant component in the biological diversity [16,17]. An extension of this concept could be applied at the (meta)population level to protected MVP.

In Mexico, wildlife conservation and management are officially based on two schemes: Natural Protected Areas (ANP, in Spanish), and Wildlife Conservation, Management, and Sustainable Utilization Units (UMA) [18-20]. The ANP have the following categories: Biosphere Reserve, Protection Areas of Flora and Fauna, National Park, Protection Areas of Natural Resources, Sanctuary, and Monument [19]. UMA can be classified in two categories: extensive (management of wild populations and habitats) and intensive (management in zoos, botanical gardens, and other places) [21]. From a total 1,972,000 km^2 of national territory, approximately 12% is in 163 ANPs [19], while 14% is in 7,955 UMA's [21]. Together these areas represent an important proportion of land dedicated to wildlife conservation and management. However, these reserves are not distributed equally in all ecosystems across country [22,23]. In addition, the size range of ANP and UMA varies from less than ten to millions of hectares; consequently the importance of each reserve for conservation of biodiversity and population persistence varies. The main function of these areas is to assure conservation and long-term sustainable use of the land through maintenance and protection of biodiversity in general, and in particular of species and threatened populations, or those with potential for human use [18]. To achieve this from a population perspective, in theory the ANP and UMA should maintain minimum viable populations. To complement biodiversity conservation, the Priority Terrestrial Regions (RTP) have been proposed [18]. These regions are not yet legal conservation areas. In some cases RTP hold completely or partially some of the actual ANP.

The white-tailed deer, *Odocoileus virginianus*, is one of the main deer species consumed by humans in rural areas and is an important trophy in sport hunting [24,25]. Its geographic distribution includes the whole country except the Baja California Peninsula and northern Sonora [26]. This wide geographical distribution shows its ecological tolerance. White-tailed deer are found in different vegetation communities such as xerophyllous shrubs, temperate oak-pine forests, tropical dry forests, semi-deciduous tropical forests, as well as in perturbed rainy forests and savanna [27]. Although this species is not placed under any category of risk by the IUCN and the Mexican NOM-059, it has been documented that illegal hunting and habitat modifications have been the main factors resulting in some local populations becoming extirpated [24,28]. In the UMA scheme, this deer represents one of the main species exploited in the country [25]. Also, ANP are ideal sites for ecological studies on this cervid [29]. The main objective of our study was to evaluate the potential of the ANP, UMA, and RTP to sustain viable populations of white-tailed deer.

Methods

Geographic information

We used the geographic distribution map of white-tailed deer proposed by Hall [26]. Even this area could overestimate the actual distribution of the species; we aimed in this study to obtain an overall view of the importance of reserves to maintaining viable populations. But the development of actual and accurate distribution maps using georeferenced collected data and habitat types through spatial analysis (GARP, MaxEnt, geostatistical correlation methods) could improve the present evaluation. The size and location of ANP, RTP, and UMA were obtained from CONABIO, CONANP, and SEMARNAT [18-20]. We excluded aquatic reserve (lagoons, coastal regions, and islands) and for reserves that included both terrestrial and aquatic zones, we used only the terrestrial part for our analyses. From the total UMA, we used only the extensive category because these considered wild populations and habitat; so we used the available information from only 1,505 UMA. With this information we created digital maps of the distribution of white-tailed deer and the ANP, RTP, and UMA using ArcView version 3.2 software.

Minimum Viable Population Data

For our purposes and according to the theoretical minimum values proposed by Franklin [9], we defined MVP as being equal to 500 and 5,000 individuals of white-tailed deer. We chose these values to evaluate whether ANP, UMA, and RTP meet the requirement of MCA to sustain an assumed value of MVP, in order to describe the conservation and management system in the country.

Determining Minimum Critical Area

In this work we propose that MCA can be estimated by considering certain MVP values and the population density (D) of this species in diverse locations. If we consider the general relationship:

$$N = D \times S \quad \text{Eq. 1,}$$

which indicates that the absolute abundance (N) of a population depends on the surface (S) of habitat that embraces that population and the mean density (individuals/km^2) at the site, and if we suppose that N = MVP, and S = MCA, then substituting and solving Eq. 1 the proposed model to estimate the MCA is:

$$MCA = \frac{MVP}{D} \quad \text{Eq. 2.}$$

In consequence, in this paper we suggest that an estimate of MCA for white-tailed deer in a certain habitat type or location can be obtained for a fixed value of MVP and considering a specific value of density. This means that the estimate of threshold values of MCA can vary depending on the conditions of the habitat which varies among sites. This is particularly the case for those species with a wide geographical distribution, such as the white-tailed deer.

Considering the information presented by Galindo-Leal [30] and recent estimates of density in several parts of the country [31-40], we define a gradient of density of 1, 5, 10, 15, 20, and 30 deer/km^2, which were substituted in Eq. 2. In consequence, for each value of MVP (500 and 5000 individuals) we estimated six threshold values of MCA.

Evaluation of each ANP, RTP and UMA

With the values obtained in the model Eq. 2, each ANP, UMA and RTP was evaluated in order to define which had the surface area that satisfied the threshold values of MCA (500 or 5,000 individuals) for a specific deer density. We assume that white-tailed deer potentially occur in any reserve within the species geographic distribution, and that all the surface area of a reserve represents white-tailed deer habitat. Later we discuss the validation of these assumptions. Selected study cases [31-40] were used to illustrate the utility of this model to evaluate specific locations to know if MCA requirements are satisfied to support MVP of this species.

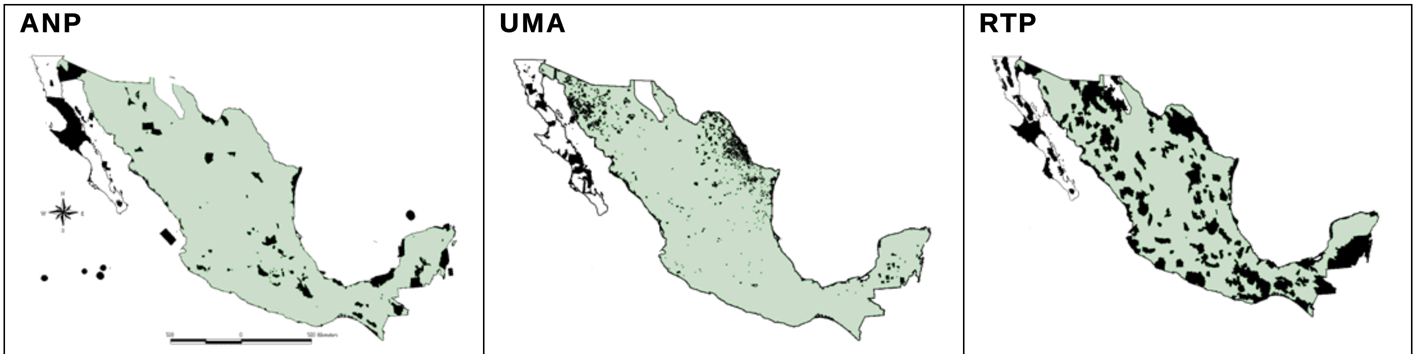

Fig. 1. Distribution (black) of the natural protected areas (ANP), wildlife management units (UMA), and terrestrial regions priorities (RTP), and potential distribution of white-tailed deer (shadow) in Mexico.

Results

Distribution size of ANP, UMA and RTP

Considering the wide geographic distribution of the white-tailed deer in Mexico, the 79% and 89% of the ANP and RTP were inside its range, respectively (Fig. 1). RTP have an average size of 328,930 ha (range 2,524 to 2,047,459 ha), and in general, they have a more homogeneous distribution in the country (Fig. 2). Considering ANP, it's clear that Biosphere Reserves, Protection Areas of Flora and Fauna, and Protection Areas of Natural Resources are the largest (Table 1). In contrast, the mean size of the evaluated UMA was 4,054 ha (range 1 to 105,683 ha), but 87% are less than 8,000 ha (Fig. 2).

Table 1. Size of the Natural Protected Areas (ANP) in Mexico. This data represent both areas inside and outside the geographic distribution of white-tailed deer. Surface is giving in hectares.

	ANP category					
Parameters	**BR**	**APFF**	**PN**	**APRN**	**S**	**M**
N	38	29	68	7	17	4
Total area	11,846,462	6,077,384	1,505,643	3,467,386	689	14,093
Mean size	311,749	209,565	22,142	495,341	41	3,523
Min	6,400	2,600	8	167	4	1,100
Max	2,493,100	2,521,800	333,800	1,553,400	168	26,100

[a] Abbreviation: Biosphere Reserve (BR), Protection Area of Flora and Fauna (APFF), National Park (PN), Protection Area of Natural Resources (APRN), Sanctuary (S), and Monument (M).

Estimation of Minimum Critical Area

The MCA increased in a non-lineal trend as the population density diminished (Fig. 3). Threshold values of MCAs are ten times larger to support an MCA of 5,000 compared to 500 deer. Specifically, a population density from 1 to 30 deer/km^2 requires 1,667 to 50,000 ha to sustain a MVP of 500 deer, and 16,670 to 500,000 ha to sustain an MVP of 5000 deer, respectively.

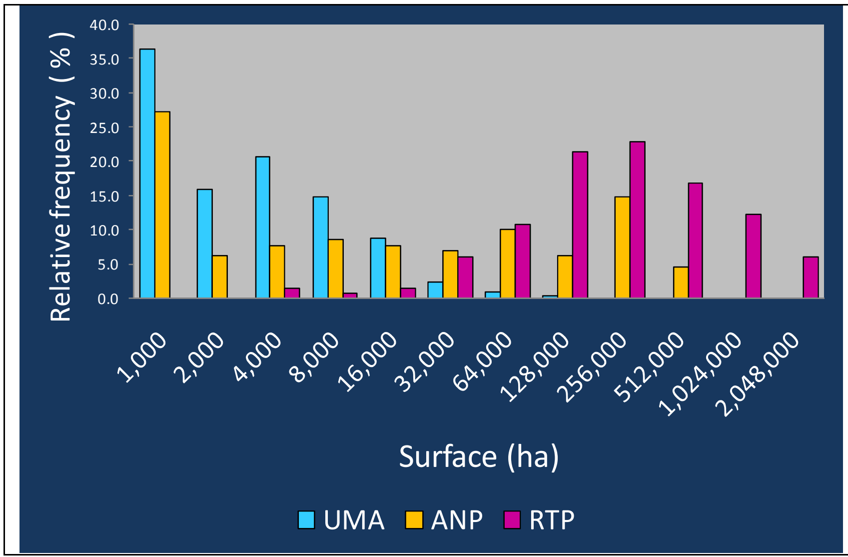

Fig. 2. Relative frequency distribution of area size of the ANP (n = 129), UMA (n = 1,505), and RTP (n = 136) included inside the geographical distribution of white-tailed deer in Mexico.

Evaluation of ANP, UMA and RTP

As a general tendency, the number of ANP, UMA, and RTP that meet the requirement of the MCA increased as the population density increased and the MCA decreased from 5,000 to 500 deer (Fig. 4). In particular, considering an MVP of 500 deer, 70-100% of RTP, 20-70% of ANP, and 1 - 50% of UMA meet the MCA for the different values of density (Fig. 4). In contrast, when we considered an MVP of 5,000 deer practically none of the analyzed UMA meets the MCA, while the percentage of ANP and RTP are affected depending on the values of density.

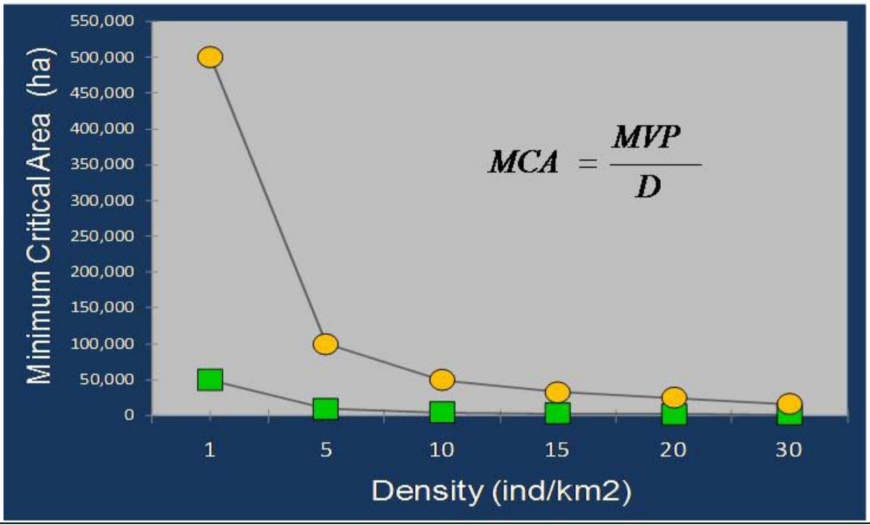

Fig. 3. Estimation of the minimum critical area (MCA) requirement to sustain a minimum viable population (MVP) of 500 (■) and 5000 (●) individuals, depending on the population density.

Specific examples

The evaluation of some specific ANP and UMA, where previous population density estimations were obtained by several authors, showed that in general Biosphere Reserves meet the threshold criterion of MCA to support a MVP of 500 deer, but fewer can support 5,000 deer (Appendix1). In general, the small size of UMA did not meet MVP criterion even to sustain 500 deer, except larger areas in the north region of Mexico.

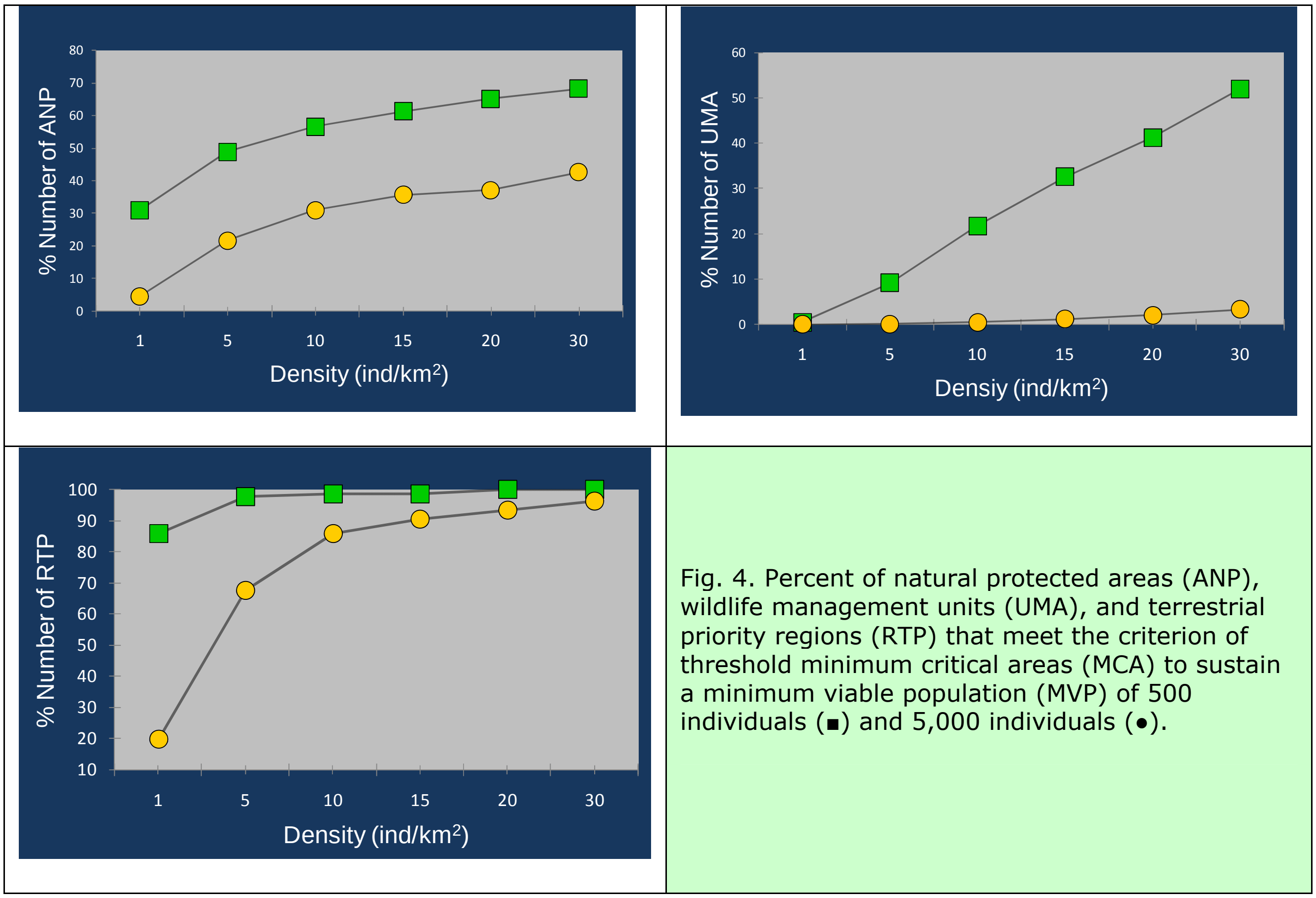

Fig. 4. Percent of natural protected areas (ANP), wildlife management units (UMA), and terrestrial priority regions (RTP) that meet the criterion of threshold minimum critical areas (MCA) to sustain a minimum viable population (MVP) of 500 individuals (■) and 5,000 individuals (●).

Discussion

Model assumptions

The validity of MCA estimates presented in this paper depends on the power of assumptions of the model used. We are not aware of published reports using population density to calculate an MCA, although Wielgus [2] applied some similar procedures to define minimum reserve sizes for grizzly bears. Density is a parameter that summarizes the social organization, behavior, spatial use, and the resources available [41]. Consequently, high density could be occurring in those places where the resources are abundant, and the interactions among the individuals allow herd formation. In these cases the density values will be larger compared to locations with limited resources or where individuals have lower home-range overlap. In those places the expected density must be lower. Therefore, the model proposed in this paper allows us to obtain a gross estimate of the MCA as a function of density. This is particularly useful for this deer species with the geographical variation in population density that has been reported by several authors [e.g., 30-40]. The other assumption in this model is that density is homogenous throughout the evaluated area. This assumption is not realistic because it is known that deer don't inhabit all habitat types; and in the same location white-tailed deer preferred specific places where resources as food, water, cover and ease of reproduction could be satisfied [30]. Thus, it's possible there is an overestimation in the evaluation of some areas to meet MCA requirements. In consequence, future studies of population viability, where demographic, genetic, environmental stochasticity, and catastrophes will be considered, could provide a more realistic estimation of MVP. Also, studies of spatial and seasonal variation of habitat use, demographics, and population dynamic will give us information on how density varies among geographical regions. Even with these limitations, the evaluation of ANP, RTP, and UMA at national levels made in this paper can provide conservation and management recommendations.

Also, the validity of MCA estimates presented in this paper depends on the validity of theoretical values of MVP used. Even though there is no single "magic" population size that guarantees the persistence of animal populations, Thomas [42] suggest an MVP of at least 5,500 as a useful goal for the preservation of existing populations in undivided habitat (e.g., for reserve design), and as a recovery target for smaller populations elsewhere. Unfortunately, population sizes in thousands are hard to attain for many vertebrates. Many of these animal populations now occur only as much smaller numbers, even in the largest national parks [43]. Several ungulate studies have estimated either MVP or MCA. For example, VORTEX simulations indicated that three local Przewalski's gazelle, *Procapra przewalskii*, populations (abundance of 70, 90, and 120 individuals) would be extinct with a 92% probability within 200 years under current conditions [44]. For wild boar, *Sus scrofa*, Howells and Edward-Jones [11] estimated that an initial population of 300 individuals had a probability > 0.95 of surviving 50 years, and they defined this number as MVP. Several contrasting MVP estimations for the genus *Odocoileus* have been used for different purposes. For example, Allen *et al.* [15] defined MVP as 50 white-tailed deer for illustrative purposes. In contrast, Reed *et al.* [45] gave a value of 13,733 individuals of this deer species as the minimum viable adult population size to 40 generations. For mule deer, *O. hemionus*, Lehmkul [46] estimated 3,680 individuals to manage the mule-deer population at its maximum potential.

Minimum Critical Area estimations

The spatial scale of conservation necessary to avoid species extinction is one of the most vigorous debates in conservation biology [47]. Neither site-scale nor broad-scale approaches alone can prevent mass extinction. Any estimate of a minimum area requirement is likely to prove controversial, but confidence is increased if different methods produce similar estimates [43]. There is a broad consensus among biologists that long-term protection of viable populations requires large reserves [5]. For example, according to an evaluation of U.S. National Parks, for most areas (100,000 ha or less) it is likely that all current reserves are unable to support MVPs of large carnivores and herbivores [5]. Salwasser *et al.* [48] proposed that lands adjacent to protected areas be included to form conservation networks of enough size (500,000 to 7.5 million ha) to support populations of 500 individuals of some carnivore species. For some North American mammal species Gurd *et al*. [43] suggested MCA from 270,000 to 1,326,200 ha to reduce probability of local extinctions. Using data provided by Allen *et al.* [15] for white-tailed deer, we recalculated and estimated an MCA of 8,130 ha to support an MVP of 500 animals. In our case, considering a density gradient between 1 and 30 deer/km^2, estimations suggest that a threshold values of MCA must be 1,667 to 50,000 ha to support an MVP of 500 animals. But from a conservation and management perspective, our estimations suggest 16,670 to 500,000 ha as an MCA for the long-term viability of a 5,000-deer population. In consequence, the values of MVP used in this paper are proposed to describe a general scene of the actual conservation and management system in the country, and suggest some management actions.

Implications for conservation and management

The majority of the reserve selection algorithms to date have worked with presence/absence data [49]. Clearly, this has limited application for managers when confronted with questions of minimum viable population size or probability of extinction. A partial solution to this is to shift from presence/absence data to quantitative data and develop algorithms that will provide solutions to questions such as, "Which set of sites when taken together will represent all species by at least some minimum population size?" Thus, the determination of an MCA to support an MVP is a critical aspect to evaluating conservation and management politics and actions.

Our results indicate that from ANP, the Biosphere Reserves, Protection Areas of Flora and Fauna, and Protection Areas of Natural Resources are the categories with the most possibilities to sustain MVP of this species. While for the UMA, their relatively small size (<1000 ha), except some of the larger ones in the northwest of the country, meant that they didn't meet the MCA even for the theoretical low value of 500 individuals. Also, the distribution of ANP and larger UMA are biased toward the northern and southeast of the country, while the RTP are distributed in the whole national territory. Therefore, RTP potentially could fulfill the MCA to sustain viable populations of white-tailed deer better than the ANP and UMA. However, unfortunately RTP do not actually have legal status.

Our evaluation suggests that a regional network system of connected ANP, UMA, and RTP is required (Fig. 5). For the case of UMA, Sisk *et al.* [23] and Weber *et al.* [50] noted that, regardless of its area, each UMA is treated as an independent unit. We agree with their conclusion that gains in biodiversity and population conservation will be enhanced by efforts to manage UMA as a network of conservation areas. If at the landscape level, the connectivity among UMA and ANP is enough to permit dispersal movements of white-tailed deer, then an MCA could be satisfied. In some northern regions, for example in the states of Sonora, Coahuila, and Nuevo Leon (see Fig. 1), it is possible to have a network system. Unfortunately, many landowners use fences to confine the deer inside their UMAs which increases population isolation and habitat fragmentation and reduces gene flow [23,50]. Therefore, in combination with more traditional park and nature reserves, the UMA scheme could provide the additional area and enhanced habitat connectivity for wildlife management and conservation [23].

We propose two ecological models that could meet the creation of conservation networks at regional scale (Fig. 5). The first is the archipelago reserve, designed to protect beta diversity in regions where this is the dominant component of the biological diversity [16,17]. Thus, an extension of this concept could be applied at the (meta)population level to protect MVP [12]. The second possible model is the source-sink system which consists of one population that has a positive growth increase (source) and another that has a negative rate of increase (sink) [51]. Thus, emigrating white-tailed deer from RTP or large ANP could ensure persistence of deer populations in UMA or small ANP, thereby constituting a dynamic population system that at landscape scale may be viable in the long term. For example, in Lacandon forest it has been proposed that this system can explain the human use of ungulates where Montes Azules Biosphere Reserve is the source, and adjacent hunting areas are sinks [52]. Thus, source-sink systems have been considered as types of metapopulations [53]. Sanchez-Rojas and Gallina [54] have suggested a metapopulation dynamic for mule deer in the Mapimi Biosphere Reserve. For white-tailed deer, preliminary study in the tropical dry forest in the Bajo Balsas, Michoacán, showed that people constantly hunted deer in very small UMAs (< 400 ha) where population density is less than 5 deer/km^2; but adjacent to the small UMAs is the Zicuiran-Infiernillo Biosphere Reserve where density has been estimated in 12-14 deer/km^2 (S. Mandujano, unpublished data). Thus, a possible source-sink population dynamic could exist in many places in Mexico, an aspect that needs further ecological investigation.

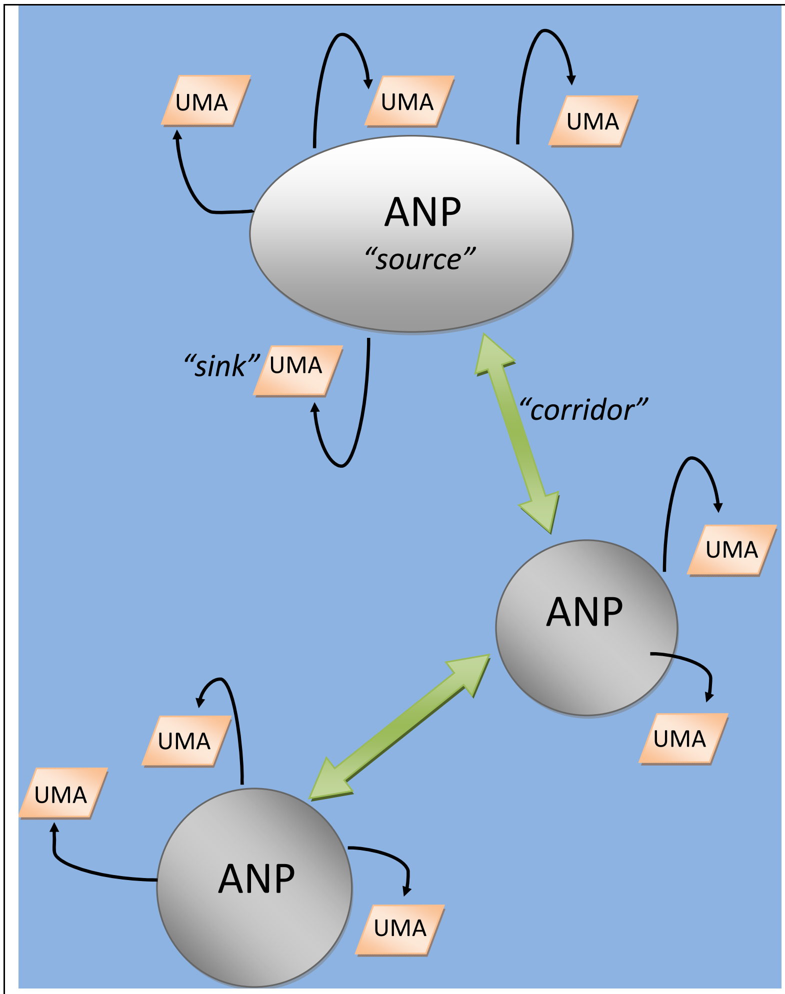

Fig. 5. Proposal scenario of regional network areas for conservation and management of white-tailed deer. According to area size, this scenario proposes a "source-sink" dynamic where large-size ANP could be a source, and small-size UMA a sink. Linking by corridors these source-sink systems could integrate an "archipelago reserve" at regional scale. In some cases, the proposal RTP could be part of this scenario to include more surfaces. The objective is to have an MCA to support an MVP of white-tailed deer.

In conclusion, we agree with the vision of Allen *et al.* [12] that characterizing MCA in patch networks, functional connectivity across habitat patches, and metapopulation dynamics for a key species will allow the identification of landscape patches key to the viability of target species, and thus the patches most critical for the conservation of viable populations. Thus, even traditional ANP are analyzed at a diversity level while UMA are analyzed at population level, it is necessary to document if these areas have the minimum area to support viable populations of other wildlife species. In consequence, there is an urgent need to integrate the participation of governmental agencies at federal and state level, research institutes, and local landowners to create incentives or provide resources for landscape-level planning [23,51,55]. The estimation of threshold values of MCA using the density model proposed in this paper could be useful not only for white-tailed deer, but also for almost any wildlife species.

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Appendix 1. Selected studies cases to illustrate the evaluation of minimum critical area (MCA) of ANP and UMA to sustain minimum viable population (MVP) of white-tailed in locations in Mexico.

Density (deer/km^2)	Location[1]	Category	Reference	Estimation of Minimum Critical Area (ha) to support:		Evaluation
				MVP = 500 deer	MVP = 5,000 deer	
15 - 30	Semi-arid habitats in northeastern Nuevo Leon, Coahuila, and Tamaulipas	UMAs	Villarreal [24]	1,666 - 3,333	16,667 - 33,333	Majority of UMA meet MCA to: MVP = 500 deer, and fewer MVP = 5,000
10 - 20	9,421 ha Mixed oak-pine forest of La Michilia Durango	ANP (BR)	Gallina [35], Galindo-Leal [30]	2,500 - 5,000	25,000 - 50,000	meet MCA to: MVP = 500 deer
5	30,661 ha Mixed oak-pine forest Bosque La Primavera Jalisco	ANP (APPF)	Valenzuela [36]	10,000	100,000	meet MCA to: MVP = 500 deer
10 - 14	13,136 ha Tropical dry forest of Chamela-Cuixmala Jalisco	ANP (BR)	Mandujano [32]	3,571 - 5,000	35,714 - 50,000	meet MCA to: MVP = 500 deer
5 - 15	247,500 ha Tropical dry forest of Zicuirán-Infiernillo Michoacán	ANP (BR)	Mandujano [unpublished data]	3,333 - 10,000	33,333 - 100,000	meet MCA to: MVP = 500 deer and MVP = 5,000 deer
13 - 20	59,131 ha Tropical dry forest of Sierra de Huatla Morelos	ANP (BR)	Corona [37], García-Sierra [38]	2,500 - 3,846	25,000 - 38,462	meet MCA to: MVP = 500 deer and MVP = 5,000 deer
1 - 5	1,000 – 5,000 ha Tropical dry forest of Mixteca Puebla	UMAs	López-Téllez et al. [31], Villarreal-Espino [39]	10,000 – 50,000	100,000 – 500,000	Not meet MCA
5	1,492 ha Semi-deciduous tropical forest Reserve El Edén, Quintana Roo	ANP	González-Marin et al. [34]	10,000	100,000	Not meet MCA
0.1	327,639 ha Tropical rainforest forest of Montes Azules Chiapas	ANP (BR)	Naranjo et al. [40]	500,000	5,000,000	Not meet MCA

[1] Location includes dsize, habitat type and name reserve.