Priorities for Biodiversity Conservation in Mexico's Northern Border

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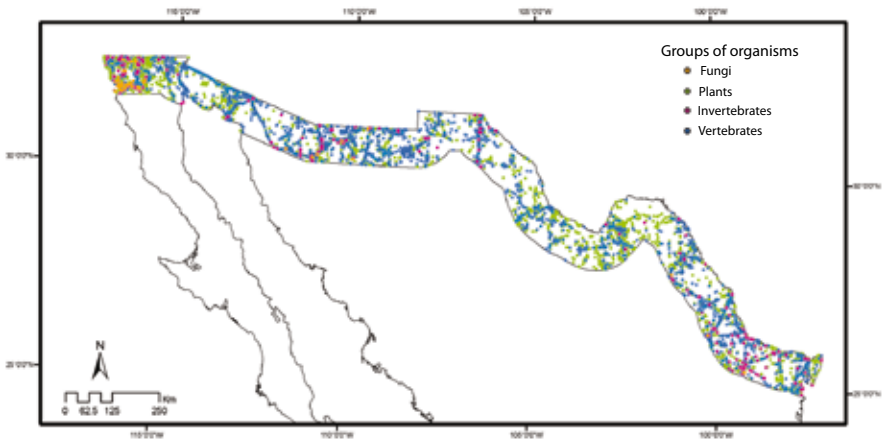
Biodiversity in Mexico's Northern Border

Despite its popularized image as a lifeless inhospitable desert, Mexico's northernmost region, which borders with the United States of America, is an area rich in its diversity of species and ecosystems, among which the Sonoran and the Chihuahuan Deserts, and wetlands such as the Colorado River Delta and Laguna Madre stand out.

The La Paz Agreement, signed in 1983, established that the border strip on the Mexican side extends from the U.S. – Mexico international border down to an imaginary line located 100 kilometers south of this border (Chávez and Suárez 1998). Within this area, there are to date 4,052 plant species registered in the National Biodiversity Information System *(Sistema Nacional de Información sobre Biodiversidad, SNIB)*, out of which 3,874 are vascular plants representing nearly 18% of the vascular flora known to Mexico (Villaseñor 2003). Also registered, are 44 species of fungi, 454 invertebrate species, mostly crustacean, 260 species of fish and 1,870 land vertebrates (44 amphibians, 184 reptiles, 1,467 birds and 175 mammals). This biodiversity is extremely high even though there are significant biases in a more detailed knowledge of the region (Figure 1).

Because of the region's biodiversity, and especially due to the high number of endemism in diverse groups of organisms, important protected areas (PA)

Figure 1. Georeferenced records of specimens in the U.S. – Mexico border for various SNIB (National Biodiversity Information System) taxonomic groups (the number of records is indicated in parenthesis): fungi (223); plants: algae (491), bryophytes (20), pteridophytes (248), gymnosperms (328), angiosperms (15,874); invertebrates: arthropods (642), crustaceans (723), other invertebrates (176); vertebrates: fish (3,411), amphibians (1,554), reptiles (8,212), birds (8,340), mammals (3,678). Of the total number of species registered, 68 are endemic and 235 are listed in some category risk in NOM-059-SEMARNAT-2001



have been declared, such as the Upper Gulf of California, El Pinacate and the Great Altar Desert, Laguna Madre and the Rio Grande Delta, Maderas del Carmen and the Santa Elena Canyon, among others. According to the biodiversity documented within the PAs along the border strip, there are 85 endangered species of plants and animals, as well as 450 rare or endemic species and 700 Neotropical migratory species; the desert pupfish (*Cyprinodon macularis*), the golden eagle (*Aguila chrysaetos*) and the endemic snakes *Natrix erythrogaster transversa* and *Coluber constrictor stnegerianus* are some examples (Chávez Alzaga *et al*. 1998).

In the context of the biodiversity in Mexico's northern border, the area extends into what Rzedowski (1991) called "Megamexico 1", which covers the entire Mexican territory and also includes the Sonoran, Chihuahuan and Tamaulipan arid regions which extend into the U.S. and which represents an attempt at an integrated description of the richness, endemism and biogeographical processes where the evolutionary processes have given rise to a moderately rich flora and specialized biological forms. This concept can be useful for understanding the phenomenon of the combination of boreal

and meridional effects with regards to both flora and fauna, in terms of the diversification of species and the determination of taxa with restricted distribution. This means many species in the U.S. – Mexico border region are shared by both countries, inasmuch as their distribution is not associated with political boundaries but with the physiographical, climate and soil conditions, among others.

The Challenges of Cross-Border Conservation

Conservation practices must be undertaken at the ecosystem level in order to protect biodiversity in a more efficient manner, and so it is necessary to go beyond the boundaries of PAs and political borders (Zbicz 2003). Specifically, on the U.S. – Mexico border we find several examples where binational cooperation is essential in order to protect rare and threatened species (Hernández *et al.* 2006, Wolf *et al.* 2006), since 31% of the species listed are registered as threatened in the U.S., while Mexico reports 85 endangered species in that region; consequently, conservation in Mexico's northern border constitutes a great challenge (van Schoik 2005). Among the hazards faced by these species is an accelerated urban and industrial growth which has unfolded since 1960 (Purcell *et al.* 2005) in Mexican border cities (*e.g.* Mexicali, Tijuana, Ciudad Juarez) as well as in the United States (*e.g.* San Diego, El Paso, Brownsville). The U.S. – Mexico border is an area with considerable economic activity which has led to significant development in the region, increasing the flow of people between the two countries; however, this phenomenon has brought about negative impacts on the environment, such as irregular human settlements, the pollution of water tables and the resulting impact on natural resources.

Invasive exotic species constitute another serious threat. The arid and semi-arid ecosystems in northern Mexico have particularly suffered more invasions of exotic species, such as buffel grass (*Pennisetum ciliare*), saltcedar or tamarisk (*Tamarix ramosissima*) and various species of fish that have displaced native flora and fauna populations (Chávez Alzaga *et al.* 1998, Glenn *et al.* 2005, Franklin *et al.* 2006).

These threats, along with the U.S. proposal to build a border fence, will generate further ecosystem fragmentation and will bring about significant deterioration of plant and animal communities, preventing free movement of wildlife populations between the U.S. and Mexico (Cohn 2007) by eliminating biological corridors and ecosystems, which would place their long term conservation in a critical state. Physical barriers, such as walls and fences

place many animal populations at risk. For example, it is well documented that the animal fences that span thousands of kilometers in Botswana have led to high death rates among wild animals, causing significant reductions in their populations over the last 20 years (Mbaiwa *et al*. 2006). A high death rate among birds has also been shown as a result of fences, specially for non-flying birds or those using vegetation at lower layers (Baines *et al*. 2007). Moreover, a fence at the Mexican border, aside from fragmenting biotic populations, will also potentially affect the behavior and circadian rhythm[1] of wild animals and the physiology in plants (Grigione *et al*. 2004, Rich *et al.* 2006) due to the effects of night lighting.

Methods for Identifying Priority Conservation Sites in Mexico's Northern Border

The program used for identifying priority conservation sites in Mexico's northern border was MARXAN version 1.8, which based on optimization methods selects the sites with the most species and ecosystems of conservation interest while simultaneously considering the minimum area affected by main threats (Ball *et al*. 2000). The analysis was performed using a 256 km^2 sampling grid on a national scale, ensuring that the assigned goals were met for all selected species and vegetation types. Here we present the results for the units (n = 1,087) that intersect with the 100 km border region.

In order to establish the desired *in situ* conservation goals to be designated as priorities for each species and type of vegetation, various criteria were considered and discussed in experts workshops organized by the National Commission for the Knowledge and Use of Biodiversity (CONABIO), during which over 2,546 coverages were analyzed and 1,450 were selected to perform the analyses. To eliminate biases in the data from collections (like those described in Figure 1) coverages of the potential distribution of terrestrial vertebrate species and plants in NOM-059-SEMARNAT-2001 were used (Table 1). Conservation goals were expressed as a ratio of the geographical distribution area of the taxon or vegetation type and criteria were defined to determine their value; such as endemicity and size of the distribution area, risk categories on the NOM-059-SEMARNAT-2001 or the IUCN threatened species lists, or if they are protected by the Convention on International Trade in Endangered

1 Circadian rythms are those biological rythms that have close to a daily frequency, that is between 20 and 28 hours.

Table 1. Examples of land vertebrates in high and very high priority sites for the conservation of biodiversity in Mexico's northern border

Group	Scientific Name	Common Name
Amphibians	*Notophthalmus meridionalis*	Black-spotted newt
	Urosaurus nigricaudus	Black-tailed Brush Lizard
	Sauromalus ater	Common chuckwalla
	Heloderma suspectum	Gila monster
	Crotalus enyo	Rattlesnake
	Crotalus exsul	Red diamond rattlesnake
	Apalone spinifera	Spiny softshell turtle
	Lepidochelys kempii	Kemp's Ridley sea turtle
	Chelonia mydas	Green sea turtle or green turtle
	Caretta caretta	Loggerhead sea turtle
Birds	*Crotophaga sulcirostris*	Groove-billed ani
	Spizastur melanoleucus	Black-and-white hawk-eagle
	Thryomanes bewickii	Bewick's wren
	Salpinctes obsoletus	Rock wrens
	Nucifraga columbiana	Clark's nutcracker
	Laterallus jamaicensis	Black rail
	Euptilotis neoxenus	Eared quetzal
	Colinus virginianus	Northern bobwhite
	Colaptes auratus	Northern flicker
	Melospiza melodia	Song sparrow
	Carpodacus mexicanus	House finch
	Caracara plancus	Southern caracara
	Cairina moschata	Muscovy duck
	Rhynchopsitta pachyrhyncha	Thick-billed parrot
	Amazona viridigenalis	Red-crowned parrot
	Ara militaris	Military macaw
	Ara macao	Scarlet macaw
	Gymnogyps californianus	California condor
Mammals	*Panthera onca*	Jaguar
	Leopardus wiedii	Margay
	Leopardus pardalis	Ocelot
	Ursus americanus	American black bear
	Ursus arctos	Brown bear
	Antilocapra americana	Pronghorn
	Canis lupus	Gray wolf
	Erethizon dorsatum	North American porcupine
	Tamiasciurus mearnsi	Mearns's squirrel
	Sciurus arizonensis	Arizona gray squirrel

Table 1. Examples of land vertebrates in high and very high priority sites for the conservation of biodiversity in Mexico's northern border *(continued)*

Group	Scientific Name	Common Name
Mammals	*Leptonycteris nivalis*	Mexican long-nosed bat
	Geomys personatus	Texas pocket gopher
	Neotoma macrotis	Big-eared woodrat
	Microtus californicus	California vole
	Scalopus aquaticus	Eastern mole
	Scapanus latimanus	Broad-footed mole

Species of wild fauna and flora (CITES). The highest conservation goals were assigned to the taxa and types of vegetation with the most restricted distribution areas or those that are most threatened. For example, within Mexico's northern border, the California condor (*Gymnogyps californianus*), eastern mole (*Scalopus aquaticus*), crasicaule shrub and primary juniper forests, all occupy less than 1% of Mexico's territory (for detailed methods see Koleff *et al*. in review).

One of the advantages of this analysis is the feasibility of selecting viable sites to try to ensure the long term survival of species and ecosystems. The feasibility is evaluated through the quantification of threats to biodiversity in each sampling unit, and it can include current and future landscape changes in variables such as land use, deforestation rates and human infrastructure (Chan *et al.* 2006). We selected 21 variables of biodiversity threats that were ranked by assigning them values according to their impact (for details see Koleff *et al*. in review). With more weight given to factors related to changes in cover, land use and fragmentation of primary vegetation, which have been recognized as the biggest threats (Wiegand *et al.* 2005) affecting diversity and biotic composition, as well as vital ecological processes such as nutrient recycling and pollination (Laurance *et al*. 2002).

Finally, an ordination analysis was performed using the PC-ORD program (McCune *et al*. 1999), to understand the relationship between high priority conservation sites and species composition. These sites were identified by N4 ecoregion (INEGI-CONABIO-INE 2007) as an ecological unifying criterion, to identify the existence of associations with these units.

Analysis of Conservation Priorities in Mexico's Northern Border

Protected Areas within Mexico's northern border strip cover 9.39% of its surface area; this percentage is below the 12% referenced as a minimum surface area that a country must have in ecological reserves (Rodrigues *et al.* 2004).

The optimization program enabled us to identify 208 priority sites out of which 85 are of very high priority, since they contain unique elements required to achieve conservation goals and they comprise 7.82% of the total sampling units within the border strip. The next group corresponds to 123 high priority sites that raise the priority surface area to 19.14% (Figure 2). However, only 8.65% of all the priority sites (1.65% of the border strip's total surface area) are under the protection of federal, state and municipal PAs.

These sites overlap with Important Bird Areas (IBA, 19.13%), Hydrological Priority Regions (HPR, 26.05%) and Terrestrial Priority Regions (TPR, 43.46%) (Figure 3). The greatest overlap occurs with TPRs, which reflect vast zones that are important for biodiversity and functional ecological integrity. For example, some of these areas have high floristic endemism (TPR 10, 83); others hold the last remnants of restricted or threatened vegetation types

Figure 2. High and very high priority sites for biodiversity conservation in Mexico's northern border. The areas with the most land use change (areas for agriculture, livestock and forestry) are shown, as well as the main highways and population centers in the northern border

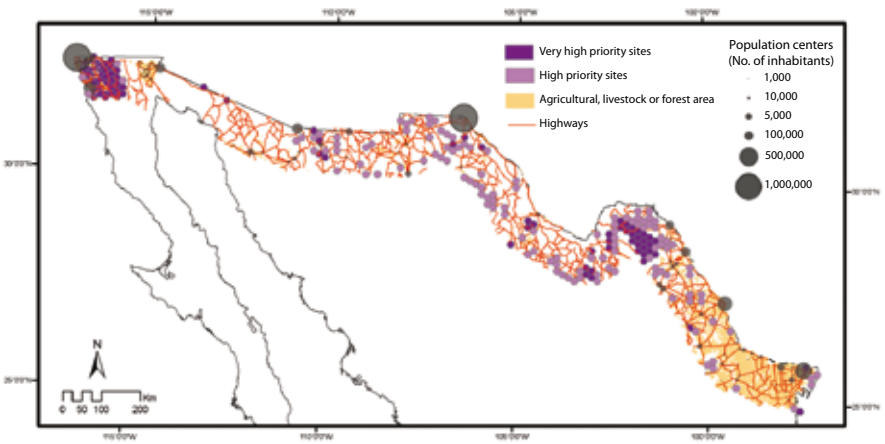
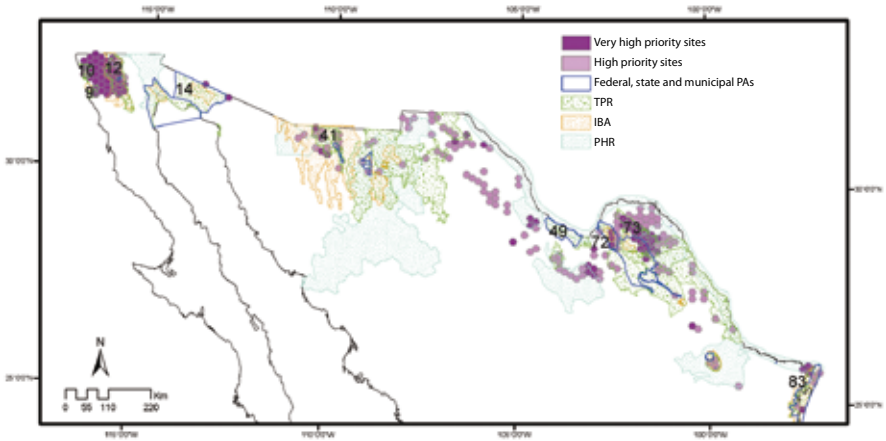


Figure 3. High and very high priority sites for biodiversity conservation in Mexico's northern border, Protected Areas (PA), Terrestrial Priority Regions (TPR), Important Bird Areas (IBA) and Hydrological Priority Regions (HPR)



(TPR 9, 10, 12); or the presence of endemic, endangered or high cynegetic value species, such as the mule deer (*Odocoileus hemionus*), grizzly bear (*Urus arctos)*, black bear *(U. americanus eremicus*), American beaver (*Castor canadensis*) and golden eagle, among others (TPR 14, 41, 49, 72, 83; see Arriaga Cabrera *et al.* 2000).

On the other hand, very high priority sites that did not overlap with any PA, TPR, HPR or IBA are also notable for having restricted or threatened primary vegetation types (*e.g.* chaparral, juniper, oak and pine forests) and are characterized by a high richness of taxonomical groups (*e.g.* cactus, pines, oaks and endemic mammals) and the presence of rare endemic or threatened species that reached very high conservation goal values, such as the Guadeloupe cypress and the California condor.

In high and very high priority sites we identified 168 species of terrestrial vertebrates that stand out for their rarity and their endemicity, either because their distribution areas are very small throughout the entire Mexican territory, because they have marginal distribution and barely cover a small portion of territory in northern Mexico, or because they are on one of the lists of species included in NOM-059-SEMARNAT-2001, IUCN or CITES. Some examples of these species are shown in Table 2. Several migratory species, whose conservation status would be greatly threatened by landscape changes in the border region, would still need to be added. The importance of cross-border cooperation ef-

Table 2. Examples of plant species in high and very high priority sites for the conservation of biodiversity in Mexico's northern border

Family	Scientific Name	Common Name
Pinaceae	*Pinus muricata*	Bishop Pine
	Pinus catarinae	Santa Catarina shrub
	Pinus johannis	Johannis pine
	Abies guatemalensis	Guatemalan Fir
Cupressaceae	*Calocedrus decurrens*	Incense cedar
	Cupressus guadalupensis	Guadeloupe cypress
Zamiaceae	*Dioon edule*	Mexican Fern Palm
Magnoliaceae	*Magnolia schiedeana*	Corpus
Lauraceae	*Litsea glaucescens*	Mexican bay leaf
Bixaceae	*Amoreuxia wrightii*	Wright's yellowshow
Cactaceae	*Echinocereus lindsayi*	Lindsay's hedgehog cactus
	Stenocereus eruca	Creeping devil cactus
	Ferocactus viridescens	San Diego barrelcactus
	Ferocactus chrysacanthus	Ferocactus
	Ferocactus johnstonianus	Johnston's Barrel Cactus
Palmae	*Brahea edulis*	Guadaloupe Palm
Agavaceae	*Agave polianthiflora*	Mescalito agave
	Manfreda brunnea	Manfreda or Runyon's huaco

forts to ensure the conservation of many of these species has been underscored, as shown by the work of Wolf *et al.* (2006) on seabirds off the rim's west coast. Some of the critical species mentioned here have been recognized in other studies as species whose conservation has received very little attention (Ceballos *et al.* 1998, EPA-Semarnat 2005, Zamora-Arrollo *et al.* 2005).

Among the group of plants in the priority sites, species of various families and types of vegetation stand out (Table 2) such as fir, oak, pine, oak-pine and juniper forests; chaparral, crasicaule shrub, Tamaulipan thornshrub, rosette-like coastal shrub, sarcocaule and submontane, mezquital, halophilous and natural grasslands, low deciduous thorn forests, and halophilous and sandy desert vegetation that is found in primary and secondary forms, which may be important to consider in conservation strategies.

On the other hand, information is required on the population status of most of the species listed, in order to evaluate the potential short term consequences of the construction of the border fence on the genetics and viability of these populations. There is no doubt habitat changes in the border region represent a threat to the evolution of natural ecosystems. It is unknown how

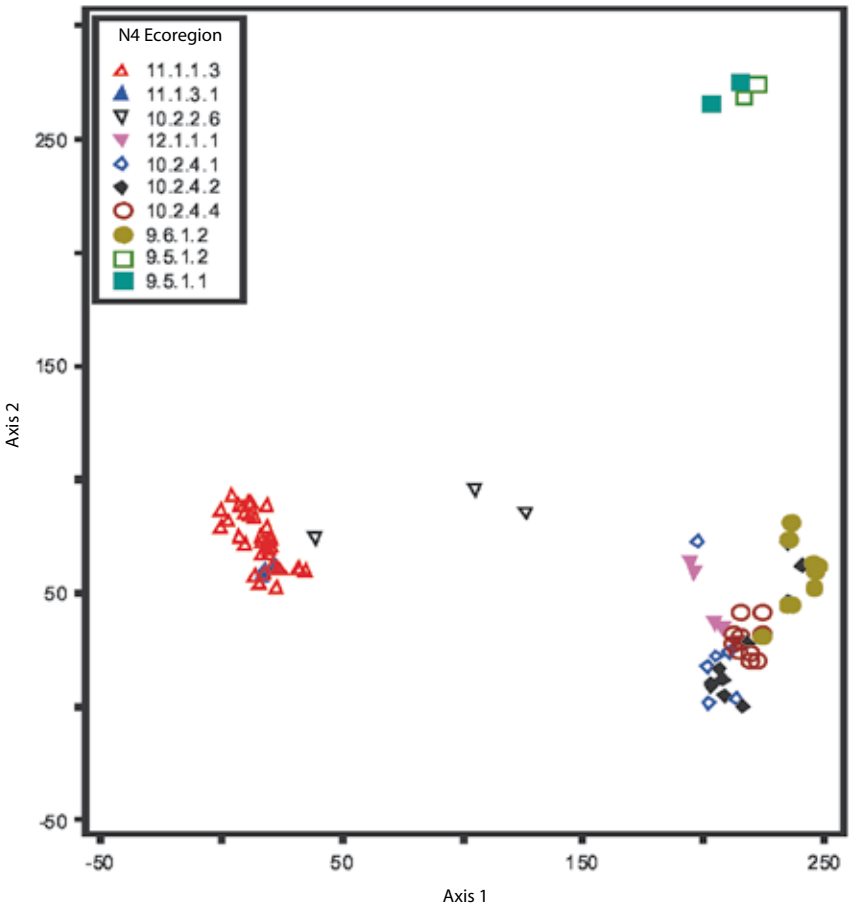
the changes will affect the landscape elements; for example, due to the incorporation of ligneous species when there is a transformation from natural grasslands to shrub, or due to the impact of introducing species that alter insect composition or other resources for the fauna that depend on them (Hernández *et al*. 2006).

According to the ordination analysis of very high priority sites, the species composition fostered by these priority sites along Mexico's northern border varies as one moves from East to West, and it is closely related to N4 ecoregions (Figure 4). This result suggests that a conservation approach must not be based exclusively on specific sites, but must consider regionalizations that take into account ecological and evolutionary criteria to ensure the continuity of the processes that take place in this region. In this sense, the need to maintain the flow between ecosystems and ecoregions free from artificial barriers is essential.

In Lieu of a Conclusion

We face great challenges in the conservation of biodiversity in Mexico, which could be heightened in our northern border by the construction of the fence.

Figure 4. Ordination analysis (DCA) of very high priority sites. This analysis shows sampling sites along quantitative axis based on their species composition. Sites clustered together have a similar composition. Axis 1 shows a longitudinal gradient along the border strip, which represents a change in species composition. The greatest difference along this axis was observed between sites located in N4 ecoregions (INEGI-Conabio-INE 2007) of western and eastern Mexico. Axis 2 shows a separation of the sites that coincide with coastal plains and wetland areas in the eastern part of the strip. Ten of the sixteen N4 ecoregions overlap with the high and very high priority sites; from west to east these are: 11.1.1.3 Hills and plains with xeric shrub and chaparral; 11.1.3.1 Hills and mountain ranges with conifer, oak and mixed forests; 10.2.2.6 Upper Gulf Deserts (Altar, El Pinacate, Mexicali-San Felipe corridor, Asuncion, Sonoyta and San Ignacio-Arivaipa basins); 12.1.1.1 Hills and plains with xeric shrub, grasslands and isolated elevations with oak and conifer forests; 10.2.4.1 Center plains in the Chihuahuan Desert, with xeric microphyll-halophilous vegetation; 10.2.4.2 Hills and mountain ranges of the Northern Chihuahuan Desert with xeric rosette microphyll shrubs 10.2.4.4 Major elevations in the Chihuahuan Desert with xeric vegetation, conifer, oak and mixed forests; 9.6.1.2 Hills and mountain ranges with xeric scrub and oak forests; 9.5.1.2 Tamaulipan Coastal Plains with xeric vegetation or no apparent vegetation; 9.5.1.1 Laguna Madre wetlands. This exercise shows it is of primary importance to include the very high priority sites in each of the ecoregions to ensure the conservation of the highest number of species and ecosystems.



In this work we have shown there is a great diversity in Mexico's northern region which requires heightened conservation efforts; particularly for the many species that are exclusive to this region, but also for the ecoregions that extend beyond our borders.

In many of the projects we have cited here, international cooperation has been a recurring theme to favor the conservation of many species in this region, some of which have suffered drastic reductions in their populations in one or both countries, which make the challenges to keep them viable even greater.

This work shows an important part of Mexico's biodiversity inhabits our northernmost region, and it is necessary to reinforce its conservation and management, for which planning exercises are highly useful. However, the

border fence does not seem the most viable solution to the illegal immigration problem in the U.S. and the related environmental problems (Cohn 2007), yet it does seem to be one more hazard added to those already faced by the flora and fauna of Mexico's border region.

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