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Potential distribution of *Ursus americanus* in Mexico and its persistence: Implications for conservation

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ABSTRACT

The black bear *Ursus americanus* is an endangered species in Mexico. Its historical distribution has decreased by approximately 80% although its current distribution is not known with precision; it is only reported to be present in the mountains of Northern Mexico. This study proposes two ensemble models: Mexicoís black bear (a) potential distribution compared with Natural Protected Areas (NPAs); and, (b) persistence areas for 2024. The current distribution variables are coniferous forest, elevation and dry forest. Suitable habitat for black bear (354,047 km^2, 18.07% of the country) was found mainly in the north of the Sonoran biogeographical zone, along the Sierra Madre Occidental, the center and south of the Sierra Madre Oriental and some northern regions of the Altiplano Norte. Comparing these areas with NPAs documented that only 12.41% of potential distribution coincided with current suitable habitat. There are unprotected areas in Sierra Madre Occidental center and central and southern of Sierra Madre Oriental. The model for 2024 indicates a reduction of suitable habitat of 64.5%, mainly in the northern Sonoran zone and the center Sierra Madre Occidental. On the other hand, areas that will persist (125,673 km^2) are located along the two main mountain ranges of Mexico. Identification of these sites will allow strengthening of long-term conservation strategies.

1. Introduction

Worldwide, there are eight species of Ursidae. The Giant Panda, *Ailuropoda melanoleuca*, is the only species considered endangered, while another six are listed as vulnerable and two (*Ursus arctos* and *Ursus americanus*) are of least concern (IUCN, 2014). In Mexico *U. arctos* was declared extinct in the 20th century. The main causes for its decline were hunting and the loss of habitat (Brown 1985; AT, 2010). The black bear (*U. americanus*) is endangered in Mexico, with hunting, habitat loss the major threats. Only the population of Serranías del Burro, Coahuila, is under special protection (AP, 1999; AT 2010). Historically, black bear distribution in Mexico included the pine-oak forest and desert areas of the Sierra Madre Occidental (SMOcc) as well as forest and grasslands of the Sierra Madre Oriental (SMO, Hall 1981). However, due to human population growth and expansion, black bear distribution has been reduced up to 80% (Garshelis, Crider, & van Manen, 2008, AP, 1999). Currently, its distribution has not been defined with precision; however, it is known that there are populations in the States of Sonora, Chihuahua, Tamaulipas, Coahuila and Nuevo León (Moctezuma & Doan-Crider, 2005).

There are two studies of the historical range of black bear in Mexico (Ceballos-Gónzalez, Blanco, González, & Martínez, 2006; Delfín-Alfonso, López-González, & Equihua, 2012). Both research used historical records, which involves a temporal incompatibility between the variables used, so that the accuracy in identifying the suitable habitat is limited (Franklin 2010). Furthermore, the algorithm used, Genetic Algorithm Rule-set Prediction (GARP) has revealed deficiencies including low precision and overestimation of the areas (Stockman, Beamer, & Bond, 2006). It is necessary to implement techniques that allow accurate identification of the distribution of black bear in Mexico. One technique recently used is the application of ensemble models from multiple ecological

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niche models (Baldwin & Bender, 2008; Rodríguez-Soto et al., 2011; Podruzny, Cherry, Schwartz, & Landenburger, 2002). The ensemble models identify areas of consistency of multiple models, generating a more accurate output (Marmion, Parviainen, Luoto, Heikkinen, & Thuiller, 2008). It is also important to identify optimal habitats in areas that will remain to strengthen conservation strategies (Cuervo-Robayo & Monroy-Vilchis, 2012). This study proposes two ensemble models: (a) potential distribution of black bear in Mexico (compared whit the Natural Protected Areas NPAs); and, (b) distribution in the future (year 2024), in order to identify black bear persistence areas.

2. Methods

2.1. Study area

The black bear is a Nearctic species (Moctezuma & Doan-Crider, 2005), so we considered as a study area the biogeographical zones of SMOcc, Sonoran region, SMO, Tamaulipeca, and Altiplano (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, 1997). Thus, the Faja Volcánica Transmexicana was the southern limit. This area includes 1,328,664 km^2 (67.81% of Mexico, Fig. 1). The vegetation includes: (1) pine-oak forest in SMOcc and SMO; (2) the arid and semi-arid (semi-desert grassland and desert scrub) in SMOcc, North and South Altiplano (Challenger, 1998).

2.2. Presence records

Presence records were obtained in two ways: (1) review of scientific literature (Calderón 2009; Carvajal-Villareal, Maehr, Caso, & Marin, 2007; Delgadillo 2001; Doan-Crider and Hellgren, 1996; Gallo-Reynoso, Suárez-Gracia, Cabrera-Santiago, & Garza-Salazar, 2007; Juárez-Casillas, Peña-Mondragón, De la Peña-Cuellar, & Cervantes-Reza, 2007; Loaiza, 2005; Martínez-Muñoz, 2001; Moreno-Valdez 1998; Moreno, 2008; Nava 2011; Sierra, Sáyago, de C. Silva, & López, 2005; Varas-Nelson, González-López, Krausman, & Culver, 2007; Verdugo 2005; Zavala, López, & Niño, 2007); and, (2) digital data bases: CONABIO (www.conabio.gob.mx) and GBIF (www.gbif.org). We filtered the records, considering only those after 1990, due to the high rate of deforestation that occurred between 1964 and 1990 (FAO, 2001). Further, in order to reduce the spatial correlation between the records, we considered only one record per pixel (Zarco-González, Monroy-Vilchis, & Alaníz, 2013). Records of black bear located in regions where the environmental characteristics are similar in SMOcc and SMO also occur in the Altiplano region of North and South (Challenger, 1998). The data were randomly divided into two groups: 75% was used to calibrate and 25% to evaluate the models (Guisan & Zimmerman, 2000).

2.3. Environmental variables

We considered environmental and anthropogenic variables related to the presence of black bear: vegetation cover; elevation; slope; distance to water bodies and, human population density (Baldwin & Bender, 2008; Delfín-Alfonso et al., 2012; Herrera, 2003; Martínez-Muñoz, 2001; Onorato, Hellgren, Mitchell, & Skiles Jr., 2003; Rogers, 1991; Rice, Ballard, Fish, McIntyre, & Holdermenn, 2009; Sierra et al., 2005; Tankersley, 1996; Verdugo, 2005). All variables were processed to a resolution of 1 km^2 and the correlation between them was analyzed in Biomapper 4.0 software to verify that the correlation coefficients were low (<0.5, de Pando and Peña de, 2007, Merow, Smith, & Silander, 2013).

For the model of the current distribution, we used vegetation and land use types of the National Forestry Inventory Series III (INEGI, 2005). The vegetation was classified as coniferous forest, dry forest, grassland, arid and semiarid vegetation, agriculture and water bodies, and each was transformed to continuous values using a moving window of 25 km^2 (Rodríguez-Soto et al., 2011). Two

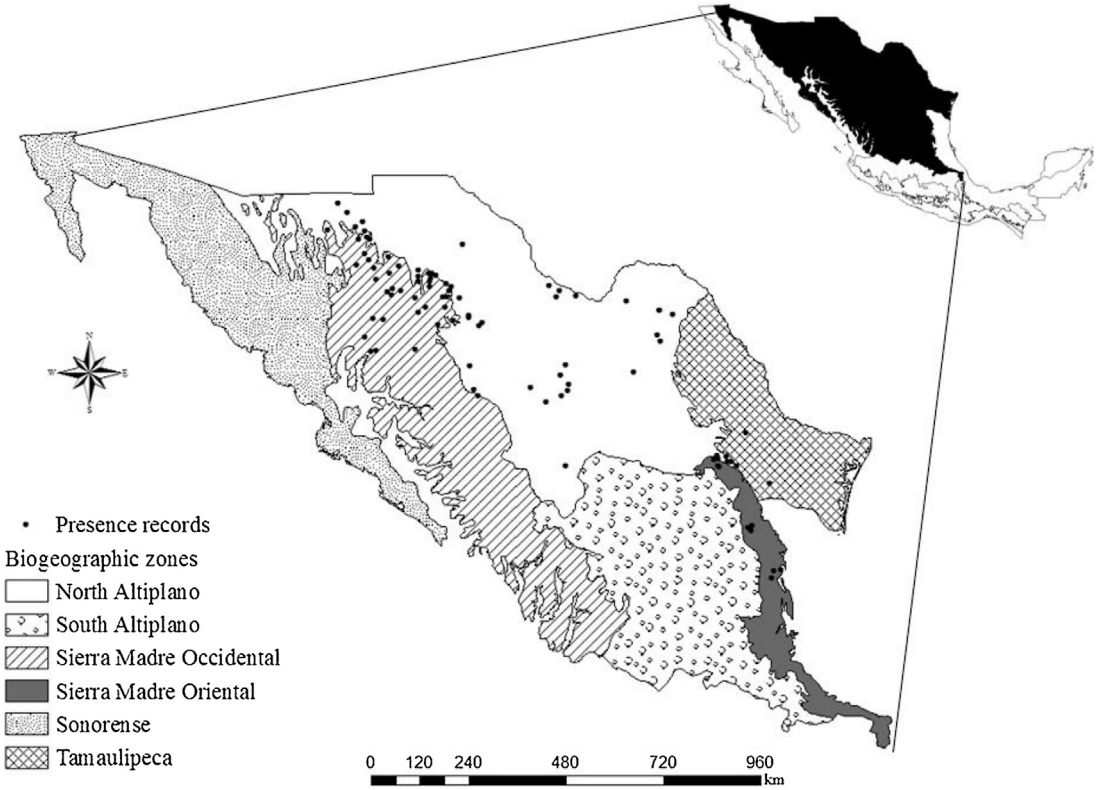

Fig. 1. Study zone and records of *U. americanus* in Mexican regions.