Biological Conservation 159 (2013) 80–87

Contents lists available at SciVerse ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Spatial model of livestock predation by jaguar and puma in Mexico: Conservation planning

Martha M. Zarco-González [a,b], Octavio Monroy-Vilchis [a,b,*], Jorge Alaníz [c]

[a] Sierra Nanchititla Biological Station, Faculty of Sciences, Autonomous University of the State of Mexico, Mexico
[b] Instituto literario 100, Centro, Toluca, Estado de México, CP 5000, Mexico
[c] Faculty of Sciences, Autonomous University of Baja California, Carretera Tijuana-Ensenada Km 106, 22800 Ensenda, BC, Mexico

ARTICLE INFO

Article history:
Received 15 May 2012
Received in revised form 23 October 2012
Accepted 4 November 2012

Keywords:
Livestock
Predation
Ecological niche model
Puma
Jaguar
México

ABSTRACT

Predation on livestock is one of the main factors that cause the felids hunting, in particular for puma and jaguar this conflict with humans is severe. Most studies have assessed the predation impacts on livestock production; however there is a spatial pattern in attacks occurrence that is feasible to analyze from ecological niche modeling. The objective of this research was to generate a risk model of livestock predation by puma and jaguar in Mexico based on environmental and livestock management variables, which allows identification of zones of risk in order to define mitigation strategies at national level. We produced a geographic ensemble model of risk of predation from three algorithms for jaguar and five for puma. The variables most positively related with predation risk by jaguar were vegetative cover percentage, percentage of free grazing animals, and altitude, whereas arid vegetation has a negative influence on predation risk. In the case of puma the variables with highest contribution were livestock density, which negatively influences on the predation risk, in addition to forest and altitude, both with a positive relation. The ensemble models are an accurate approach to delineating the zones of predation risk by felids; however at a regional scale the environmental characteristics that favor predation may be different. It is recommended that researchers carry out studies for each biogeographic province that facilitate the identification of specific patterns and the definition of mitigation strategies most suitable for each one.

1. Introduction

Populations of large carnivores are declining worldwide due to the loss or fragmentation of their habitat, and by direct hunting of the carnivores or their prey; currently, 17% of the species are threatened (IUCN, 2011). The hunting of felids takes place in response to their supposed predation on livestock (Holmern et al., 2007; Kissui, 2008; Gusset et al., 2009); this problem affects 75% of felid species worldwide, and in particular is severe for puma and jaguar (Inskip and Zimmermann, 2009). In previous studies, data on felids hunted in retaliation for predation have been reported, which range from seven pumas killed per year on average in a ranch in Sao Paulo to 150 pumas and jaguars in Alta Floresta, Brazil (Inskip and Zimmermann, 2009).

Hence, it is evident that a fundamental topic in large cats' conservation is the analysis of the conflicts with livestock holders. This issue has mainly been approached by describing the impact of predation on livestock production and identifying factors related with the predation levels (Patterson et al., 2004; Kolowski and Holekamp, 2006; Azevedo and Murray, 2007; Van et al., 2007; Palmeira et al., 2008; Iftikhar et al., 2009). Other authors have observed differences in the environmental characteristics of sites with and without predation (Jackson et al., 1996), and this may be an indicator of conditions inherent to the sites that influence on the risk (Stahl et al., 2002). Among the proposed environmental variables that may be related with the frequency of attacks are proximity to forest zones (Mazzolli et al., 2002; Stahl et al., 2002; Azevedo and Murray, 2007; Palmeira et al., 2008), the vegetation type (Rosas-Rosas et al., 2010), altitude (Lui et al., 2006), topography (Stahl et al., 2002; Michalski et al., 2006; Kissling et al., 2009), density of livestock and wild prey (Treves et al., 2004; Bagchi and Mishra, 2006; Kolowski and Holekamp, 2006), distance to protected areas, human settlements, roads, and water sources (Lui et al., 2006; Van et al., 2007; Gusset et al., 2009; Rosas-Rosas et al., 2010). An approach that may be useful in decreasing the severity of the conflict is to anticipate its spatial location and to propose preventive actions in specific areas, optimizing economic and human resources.

A commonly used tool to plan strategies of wildlife management, which relates ecological variables and spatial processes, are ecological niche models (Gibson et al., 2007; Zarco-González et al., 2012), the modeling provides estimates of occurrence

* Corresponding author at: Instituto literario 100, Centro, Toluca, Estado de México, CP 5000, Mexico. Tel.: +1 722 296 55 53.
E-mail addresses: martha.zarco.g@gmail.com (M.M. Zarco-González), tavomonroyvilchis@gmail.com, omv@uaemex.mx (O. Monroy-Vilchis).

0006-3207/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biocon.2012.11.007

probability of these processes in the study area. This technique has been applied to study the relations between environmental parameters and richness of species (Araújo and Williams, 2000; Ferrier et al., 2002; Scotts and Drielsma, 2003; Mac Nally and Fleishman, 2004), invasive potential of exotic species (Peterson, 2003; Goolsby, 2004), and species distributions (Bakkenes et al., 2002; Hugall et al., 2002; Araújo et al., 2004; Peterson et al., 2004; Skov and Svenning, 2004; Thomas et al., 2004; Thuiller et al., 2005; Rodríguez-Soto et al., 2011).

By applying this methodology to the study of human-wildlife conflict, from the location and characterization of the sites where predation on livestock is present, it is possible to spatially predict the zones of predation risk, as well as to identify the variables that propitiate this interaction. This enables planning actions to manage livestock and predators in specific zones to minimize the conflicts, optimize livestock production, and reduce the hunting of wild felids. The objective of this study was to generate a risk model of livestock predation by puma and jaguar in Mexico based on environmental and livestock management variables. The model further allows identifying and prioritizing of zones of felid predation risk in order to develop mitigation strategies at national level.

2. Materials and methods

2.1. Study area

Mexico is located in northern America, its territorial extension is 1,953,162 km^2 (Fig. 1). Its extreme coordinates are: 14°32′27″ south, 32°43′06″ north; 86°42′36″ east and 118°27′24″ west (INEGI, 2011). Mexico possesses a varied topography, more than 65% of the country is above 1000 m above sea level and nearly 47% of the surface has slopes over 27% (UNAM, 1990; Mittermeier and Mittermeier, 1992). In conservation importance, Mexico hosts between 8% and 12% of the total of the species on the planet (Mittermeier and Mittermeier, 1992), including six feline species, of which puma (*Puma concolor*) and jaguar (*Panthera onca*) are the largest.

The records of attacks on livestock by puma and jaguar in Mexico were collected in three ways: (1) databases of the Mexican government, Secretariat of Environment and Natural Resources (SEMARNAT), Pronatura (civil association) and technical reports (Núñez, 2007a); (2) review of scientific literature: theses (Bueno-Cabrera, 2004; Villordo-Galván, 2009), books (Brown and López, 2001; Rosas-Rosas and López-Soto, 2002; Caso, 2007; Cruz et al., 2007; Leyequién and Balvanera, 2007; Lira and Ramos-Fernández, 2007; Navarro et al., 2007; Núñez, 2007b), and papers (Rosas-Rosas et al., 2008; Chávez and Zarza, 2009; Zarco-González et al., 2012); (3) and field work in different states of the country (states of Mexico, Chihuahua, Yucatán, Campeche, Baja California and Guerrero). Approximately 78% of predation data were recorded at the site of attack with GPS devices and 22% were inferred using Google Earth and maps and descriptions presented in the original sources. A database of predation events was produced with the records specifying date, predator species, place of attack, and geographic coordinates (Fig. 1).

Considering the reports of other studies in relation to the influence of the environmental factors on the predation risk (Stahl et al., 2002; Treves et al., 2004; Bagchi and Mishra, 2006; Kolowski and Holekamp, 2006; Lui et al., 2006; Michalski et al., 2006; Van et al., 2007; Gusset et al., 2009; Kissling et al., 2009; Rosas-Rosas et al., 2010), the variables used to characterize the sites of attack were grouped in three types: landscape, livestock management,

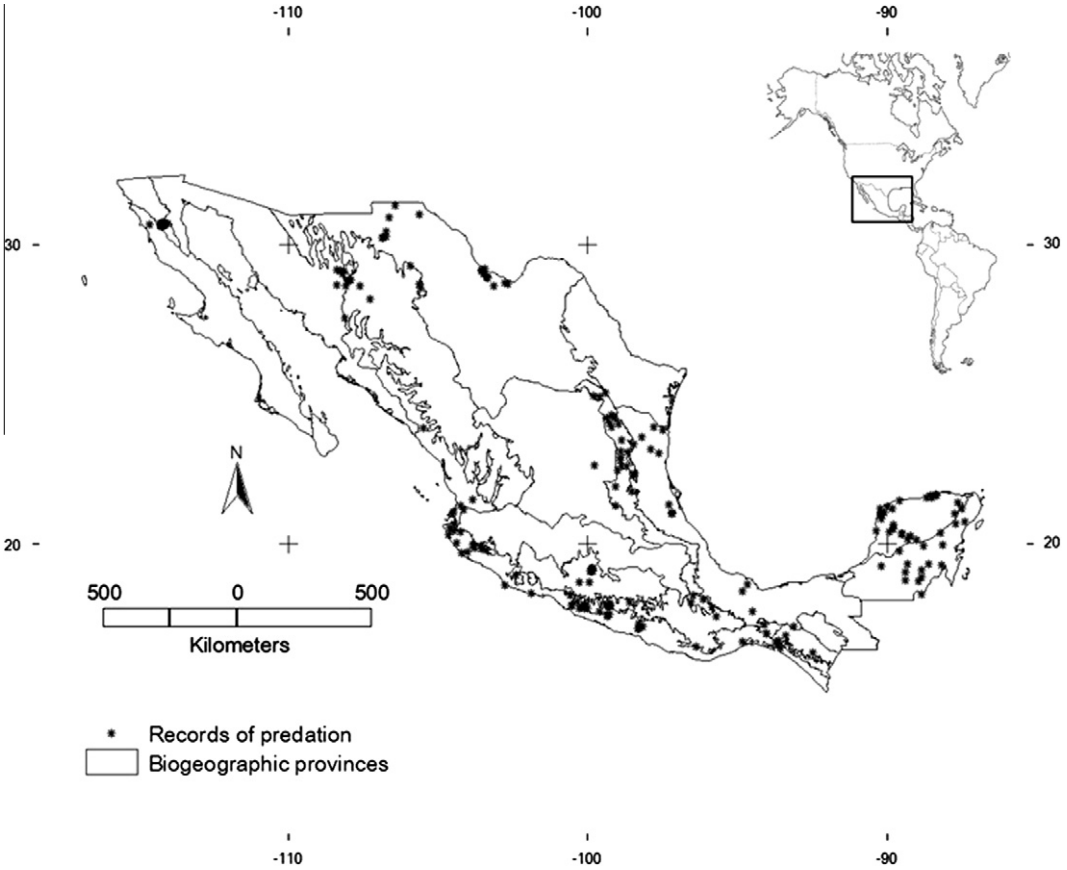

Fig. 1. Mexico location and records of predation by jaguar and puma.