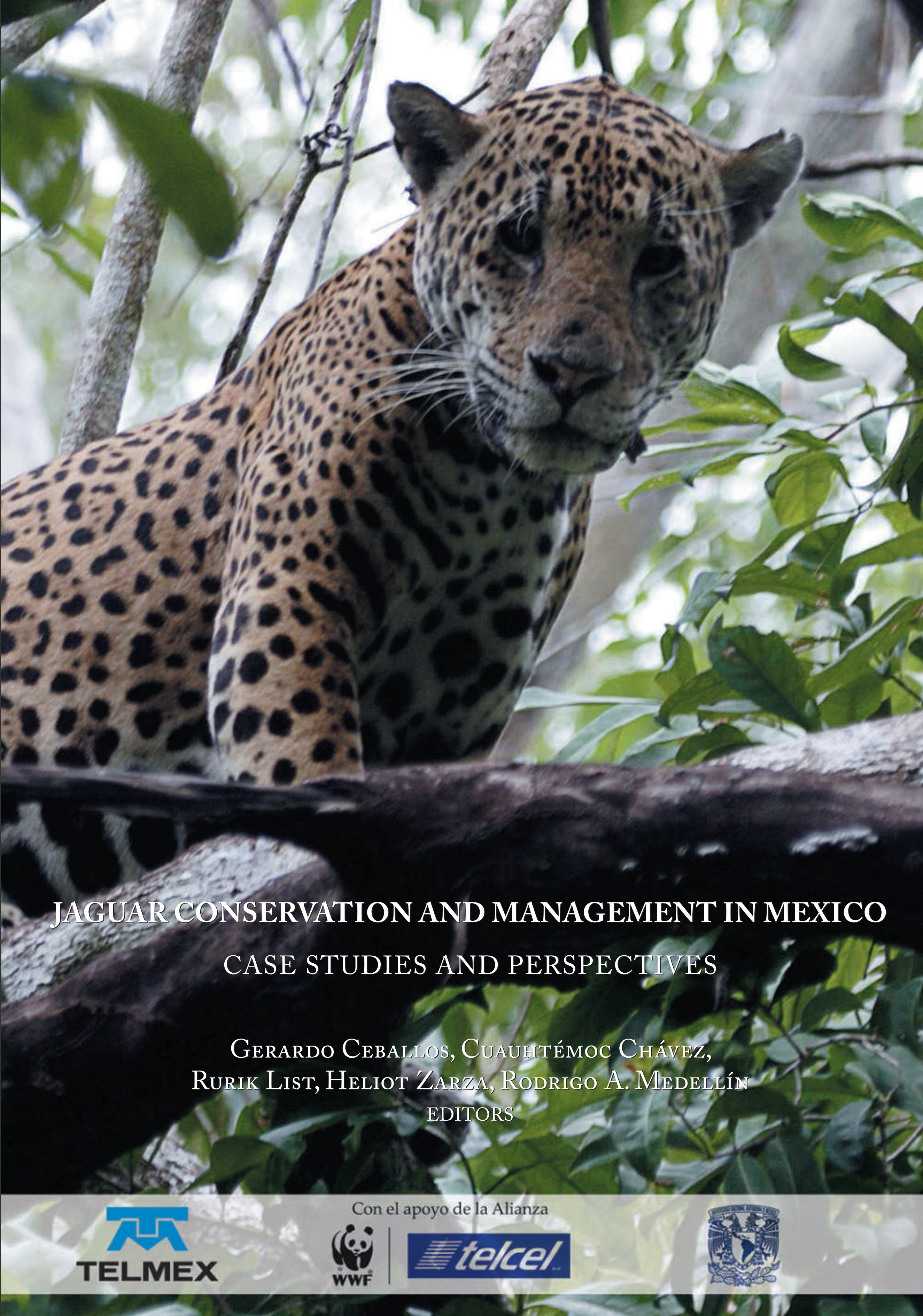

JAGUAR CONSERVATION AND MANAGEMENT IN MEXICO

CASE STUDIES AND PERSPECTIVES

Gerardo Ceballos, Cuauhtémoc Chávez,
Rurik List, Heliot Zarza, Rodrigo A. Medellín
EDITORS

Con el apoyo de la Alianza

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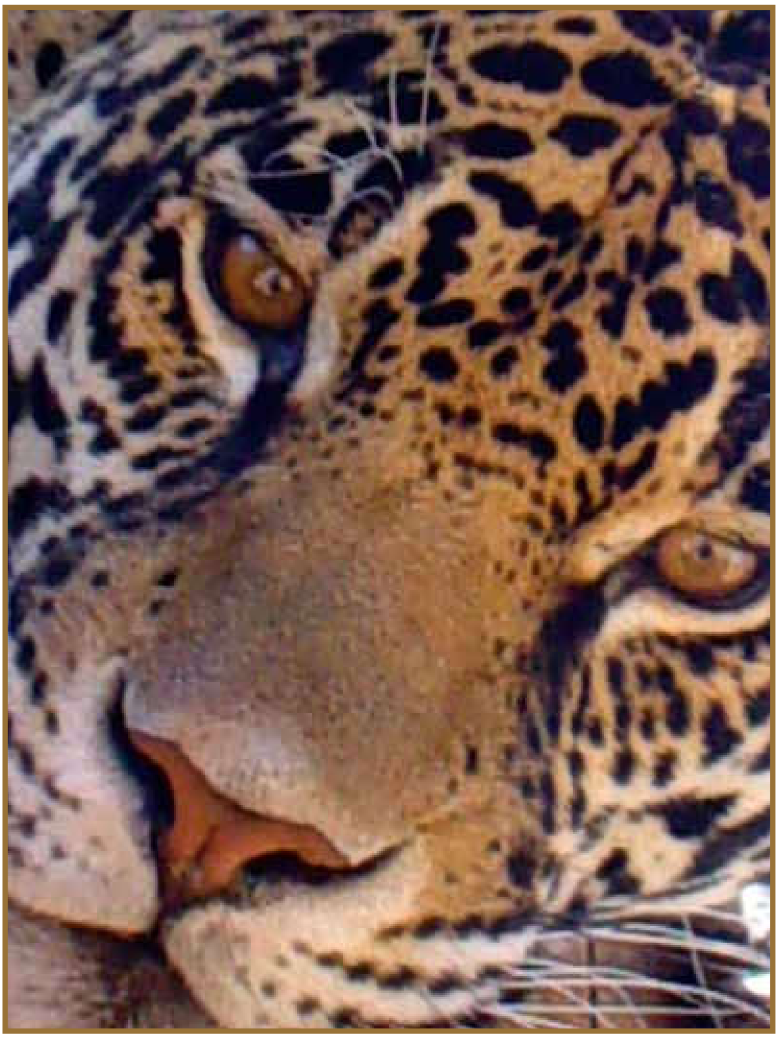

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Contents

Introduction

Hearing the roar of a jaguar behind the shrubs in a tropical forest is a humbling experience. Today, as during pre-colonial times, jaguars are still admired and feared; the massive monolithic jaguar heads left by the Olmecs; the *Chac Mool* sculptures representing *Balam*, the jaguar for the Mayan; the Aztec jaguar warriors; and diverse deities across the cultures throughout the range of the species are evidence of the influence that the largest of the American felids had in the Mexican culture.

But jaguar is more than culture; by being a top predator, its presence influences the ecosystems where they inhabit to the extent than when the large felids are absent, tree species diversity plummets and dramatic changes on the density of organisms, from ants to monkeys, occur. This, however, has not been enough to insure their permanence in the wild.

Thousands of jaguars were legally hunted as trophies for the fur market, severely reducing populations across the range until commercial trade was banned in 1973. As an example, between 1950 and 1965, 11 000 jaguar skins were traded from Brazil, and thousands more were exported illegally. Roughly 1 300 jaguar skins were legally exported from Mexico to the United States between 1968 and 1970. The prohibition of sport hunting in Mexico in 1987 was not enough to protect the jaguar, since illegal hunting for trophy or to prevent livestock predation continues; about 100 individuals are still illegally hunted in Mexico every year. At the same time, the large tracts of forest that the species needs to survive have been decreasing in size and integrity, isolating the populations and getting them in close proximity to people and conflict, factors which have reduced their numbers or caused their local extinction.

But in the XXI century, jaguars are still an icon among the wild things of Nature. This has prompted people and organizations to actively engage in the protection of this species and its habitat. Reserves have been created or expanded to allow jaguars room to roam; research to determine their conservation needs is rapidly increasing; incentives to reduce the risk of being killed are being applied, and education and information efforts are spreading. This book reflects the interest and commitment on the conservation of jaguar in Mexico, which has been growing since the establishment of the of the Technical Advisory Subcommittee for the Recovery of the Jaguar (*Subcomité Técnico Consultivo para la Recuperación del Jaguar*) in 2000, followed by the publication of the Jaguar Recovery Program, the designation of 2005 as the Year of the Jaguar, and the listing of the species as one of the top 5 priority species for recovery by the Federal Government.

Scientists and conservationists working with jaguars and issues which, directly or indirectly could have an effect on the conservation of the species, got together to share experiences, carry out a national jaguar census, and developed a National conservation strategy in six annual symposia held from 2005 to 2010. These symposia were financially supported by the Commission on Protected Areas (Conanp) of the Mexican Federal Ministry of the Environment, Telmex, Alianza WWF–Telcel, the Institute of Ecology of the National University of Mexico, Ecociencia, and other institutions. The six symposia took place at the Cuernavaca Golf Club in the state of Morelos, Mexico.

The present book compiles the presentations and work conducted during the three first symposia, and is divided in two parts. Part I includes case studies by Jaguar specialists on the distribution or the ecology of the jaguar in all the regions where the species occurs in Mexico, and Part II deals with conservation and management priorities for the species, methods to determine the population size and health status of wild populations, as well as conservation strategies that include ecosystem services, community watch programs and strategies launched by the Mexican Ministry of the Environment and Natural Resources for the conservation of the species.

It is a privilege for us to be players in this joint conservation effort, which would not have been possible without the enthusiasm and dedication of our colleagues, authors of the chapters and champions of Jaguar conservation, to whom we are deeply grateful. The support from the institutions that trusted us in this endeavor allowed the symposia and books to become a reality. The Jaguar epitomizes the great environmental challenges of the XXI century, our future is linked to its survival, and only a united effort will succeed in insuring its permanence on Earth. With this book we capture the effort of many people over the years to see our mightiest cat persist, and trust it will influence and help others to sum on our collective efforts.

The Editors
Ciudad Universitaria, Mexico City
September 2011

PART I

DISTRIBUTION AND ECOLOGY

Conservation of jaguars and pumas in northeastern Sonora

Octavio C. Rosas Rosas, Raúl Valdéz, and Louis C. Bender

Resumen

Se localizó una población residente de jaguar en el noreste de Sonora, México, aproximadamente a 270 km de la frontera entre Sonora-Arizona. Es posible que esta población sea la fuente de los jaguares observados desde 1996 en Arizona y Nuevo México. El jaguar y puma en esta región se encuentran amenazados debido al control de depredadores. Es común la pérdida del ganado en esta área y en la mayoría de las mismas se culpa a estas especies. El jaguar se alimentó de ganado y venado cola blanca principalmente, mientras que el puma lo hizo de venado cola blanca y de mamíferos medianos y pequeños. Para reducir la pérdida de jaguar y puma se creó una Unidad de Manejo y Aprovechamiento de la Vida Silvestre (UMA) en el 2003, con el objetivo de generar fondos para conservación. Se inició el manejo del venado cola blanca para cacería de trofeos en el 2004. Los fondos generados con la cacería de venado están siendo usados para mejorar el manejo de la ganadería para minimizar y mitigar la depredación sobre el ganado.

Palabras clave: conservación, Sonora, jaguar, puma.

Abstract

A breeding population of jaguars was found in northeastern Sonora, Mexico about 168 miles from the Arizona-Sonora border. This population is, most likely, the source of the jaguars recorded in Arizona and New Mexico since 1996. Cattle losses are common in this part of Sonora and cattle ranchers claim that most of the losses are due to jaguar and puma predation. Jaguars fed primarily of cattle and white-tail deer, while pumas did on white-tailed deer and medium and small mammals. The main threat to jaguars and pumas in northeastern Sonora is predator control in response to jaguar and puma predation on livestock. A wildlife management unit was created in 2003, specifically to conserve jaguars in northeastern Sonora. It encompasses approximately 400 km^2 and was created to generate funds for jaguar conservation. Management of white-tailed deer for trophy hunting was initiated in December 2004. Funds generated through white-tailed deer hunting are being used to improve cattle management, and to mitigate and minimize jaguar predation on livestock.

Keywords: conservation, Sonora, jaguar, puma

Introduction

The Program for the Conservation of the Jaguar (*Panthera onca*) in the Sierra Alta mountain range in Sonora began in 1999 with a search for the possible source of dispersal of the specimens recorded in Arizona, USA, in 1996 and 1997 (Glenn, 1997). Between the summers of 1999 and 2000, a resident population of jaguars was found in the municipality of Nácori Chico, in the basin of the Aros-Bavispe rivers, about 200 km south of the border between Mexico and the USA (Martínez-Mendoza, 2000; Valdez *et al.*, 2000). The second phase of the study was to determine the ecological status of the species in the region (Rosas-Rosas, 2006).

The first phase of the study showed that the jaguar is a resident species and that the habitat is appropriate for its survival (Martínez-Mendoza, 2000). However, the prey base is limited compared to other regions in the species' range in Mexico (Aranda and Sánchez-Cordero, 1996; Núñez *et al.*, Valdez *et al.*, 2000). It also showed that the collared peccary (*Tayassu tajacu*; Aranda, 1994), one of the most frequent prey of the jaguar in other areas, was uncommon, and that the most common prey was the white-tailed deer (*Odocoileus virginianus*; Rosas-Rosas, 2006). Livestock losses are common and predator control is implemented as a response. In northern Mexico such measures are often used as a preventive step against predation –especially by felids– on livestock and game such as deer, and more importantly bighorn sheep (*Ovis canadensis*; Rosas-Rosas and López-Soto, 2002; Rosas-Rosas *et al.*, 2003).

Jaguar records were sporadic from the beginning of the study. In this region, jaguars were found to live in ecotone areas between semi-arid shrubland, sub-tropical forest and temperate forest. Predominant land use was poorly managed extensive livestock farming. In the second phase of the study, abundance was estimated by identifying individuals through tracks and camera trapping. The results showed a density of one jaguar/100 km^2, whereas estimations for pumas were two individuals/100 km^2 (Rosas-Rosas, 2006).

In northeastern Sonora, livestock farming has been the most important economic activity since the 17th century (Martínez-Caraza, 1983). Although the region has an extreme climate, the severe droughts of the last few years have had a significant impact on livestock farming (Rosas-Rosas, 2006). Due to heavy losses of livestock, farmers have become intolerant to predation events and control predators when livestock is attacked by jaguars or pumas (*Puma concolor*); (Rosas-Rosas *et al.*, 2010). To react to this situation, a Wildlife Management Unit was set up with the jaguar as a flagship species in the framework of a program. The program took shape thanks to the continuous dissemination of the research findings to the community, the support of the federal authorities (Semarnat) and the willingness of the landowners to diversify their activities. Funds generated by the Wildlife Management Unit are being used to minimize and mitigate jaguar and puma predation on livestock (Rosas-Rosas, 2006). This provides an alternative income to livestock farmers with a minimum investment, which allows them to tolerate losses caused by predators and protects local wildlife (Rosas-Rosas and Valdéz, 2010). The main goal of the program is to re-establish a cooperation scheme with the community to solve the social and economic challenges associated to predators in a rural economy based on livestock farming.

The specific objectives of this study were: a) to estimate predation on livestock by jaguars and pumas, and b) set up a community-based jaguar conservation program underpinned by the sustainability of natural resources.

Study area

The study area is located in the Sierra Madre Occidental, about 270 km south of the Sonora-Arizona border, and 60 km south west of the municipal seat of Nácori Chico. It encompasses about 400 km^2 and includes 11 private livestock ranches. The main economic activity in the region is extensive livestock farming.

The Sierra Madre Occidental has a great variety of habitats, which include pine (*Pinus* spp.) and oak (*Quercus* spp.) forests, subtropical scrub and patches of tropical deciduous forest (Brown, 1982). Elevation ranges from 500 to 2700 m. The Aros River, the largest in the region, is at the southern end of the study area. The landscape is rugged, with small creeks. Average annual rainfall is 400 mm in valleys and up to 1000 mm at higher elevations (Marshall, 1957). There are two main seasons: the dry season, from March to June, and the wet season, from July to September.

Subtropical scrub is the predominant vegetation type (Brown, 1982). Dominant plant species are *Coursetia glandulosa, Lysiloma divaricata*, mesquite (*Prosopis juli-*

The study area, in northeastern Sonora, is about 200 km south of the Mexico-US border.

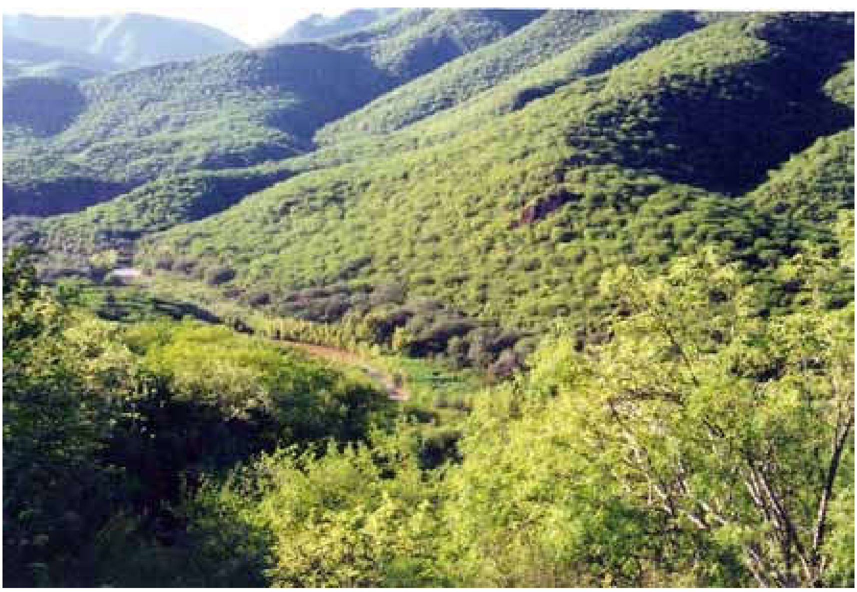
flora), *Bursera* spp., *Dononaea viscosa*, common sotol (*Dasylirion wheeleri*), *Erythea roezlii*, *Sabal mexicana*, *Opuntia* spp., *Piscidia mollis*, *Mimosa* spp., organ pipe cactus (*Lemaireocereus thurberi*), and carelessweed (*Amaranthus palmeri*).

The most common terrestrial mammals are white-tailed deer (*Odocoileus virginianus*), jackrabbit (*Lepus californicus* and *L. alleni* spp.), rabbit (*Sylvilagus audubonii*), white-nosed coati (*Nasua narica*), collared peccary (*Tayassu tajacu*), opossum (*Didelphis virginiana*) and rock squirrel (*Spermophilus variegatus*). Other carnivores that occur in the area include coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), racoon (*Procyon lotor*), neotropical river otter (*Lontra longicaudis*), bobcat (*Lynx rufus*), ocelot (*Leopardus pardalis*), skunk (*Mephitis macroura* and *M. mephitis*, *Spilogale gracilis*, *Conepatus leuconotus*), ringtail (*Bassariscus astutus*), and American badger (*Taxidea taxus*; Hall, 1981; Leopold, 1959).

Methods

To determine the consumption of livestock by jaguars and pumas, scats were collected along trails used by livestock and wildlife, and in caves, mountain passes and riparian areas. Remains of prey species were also recovered. Related tracks and the predation pattern of each species were taken into account to decide what species the scats and remains of prey should be attributed to (Aranda, 2000; Rosas-Rosas, 2006; Rosas-Rosas *et al*., 2008). In order to assess the importance of the prey of jaguars and pumas including livestock, we estimated frequency and percentage of occurrence, as well as consumed biomass (Ackerman *et al*., 1984; Núñez *et al*., 2000).

Field research was combined with interviews to farmers to estimate the significance of predation by jaguars and pumas on livestock (Rosas-Rosas, 2006). During



Riparian vegetation in the wet season, with piedmont scrub and tropical deciduous forest.
Photo: Octavio C. Rosas Rosas

the field research period, we looked for prey remains in sites where cattle ranchers claimed to have losses caused by predators. When fresh evidence of livestock predation was found, the predator species was determined. The information obtained in the field was compared with the claims of farmers (Rosas-Rosas *et al.*, 2008).

Results and discussion

The diet of jaguars was found to be composed mainly of livestock and other medium-sized mammals, whereas pumas preyed upon mainly on white-tailed deer (Rosas-Rosas, 2006; Rosas-Rosas *et al.*, 2008). In the dry season, livestock farmers do not have many choices of places to move their animals to, as places where water is available are usually located in densely vegetated areas. These are the areas used by large felids, which inevitably leads to conflict. However, since 2004 there has been a significant increase in the natural prey of jaguars and pumas –white-tailed deer, collared peccary, white-nosed coati, and other medium-sized and small mammals– (Rosas-Rosas, 2006). This may be the result of an increase in rainfall since mid - 2004, which has led to greater vegetation cover and water availability.

In this region of Sonora, livestock farmers claimed about 400 livestock loses due to predation in 2004-2005. Yet, the field study proved that less than 10% of losses were caused by jaguars or pumas (Rosas-Rosas *et al.*, 2008). Predation by felids was not significant for the overall livestock farming operations of the 11 ranches in the study area. However, if most of the predation events take place in one ranch, this can have a severe economic impact on the ranch and put it out of business (Rosas-Rosas, 2006).

Subtropical scrub, the dominant vegetation in the study area.
Photo: Alejandro Juárez Reyna

Conservation efforts

The results showed that predator control is one of the main threats to the survival of jaguars and pumas in the jaguars northernmost habitat. A conservation program has been developed in an attempt to minimize the impact of such activities. The program includes workshops to show livestock farmers how to prevent and reduce predation on livestock and meetings with landowners in the study area. Official meetings were also held with researchers, federal, state and municipal authorities, and livestock farmers, both in the municipal seat of Nácori Chico and Hermosillo. One of the main actions undertaken in the community was an environmental education workshop held in the municipality of Nácori Chico in April 2004. The workshop involved visiting four communities in the municipality, where 375 preschool, primary and secondary students participated out of 415 students in the area. The importance of natural resources was highlighted, the findings of the research were shared with the students and feedback was obtained on their perception of local wildlife (Rosas-Rosas and Valdéz, 2010).

The meetings mentioned above also led to consolidating the agreement on the conservation of the jaguar signed by landowners, researchers and the federal government. In exchange for not killing jaguars, landowners were promised that wildlife in their ranches would be subjected to a managed hunting regime, as a partial compensation for possible damages caused to livestock by jaguars (Rosas-Rosas, 2006). Registration of the Wildlife Management Unit called Programa de Conservación del Jaguar en la Sierra Alta de Sonora was approved in 2003 (UMA-SEMARNAT-292-SON). This conservation program aims at promoting ecotourism, conservation hunting and adventure tourism in the region to lay the necessary foundations for a long-term conservation program for the jaguar and other species such as the southern river

Environmental education workshops/programs were used to strengthen the jaguar conservation program in northeastern Sonora. Preschool, elementary and secondary students learned facts and values about local wildlife.
Photo: Octavio C. Rosas Rosas

otter, ocelot, black bear (*Ursus americanus*), and thick-billed parrot (*Rhynchopsitta pachyrhyncha*), just to mention a few endangered species that occur in the area.

The objective is to increase community involvement in the conservation program and bring together Mexican and foreign research institutions, American government agencies such as the Arizona Game and Fish Department, New Mexico Department of Game and Fish, United States Geological Survey, and non-governmental agencies such as the Wildlife Conservation Society and Primero Conservation Outfitters LTD. The creation of a biological station in Nácori Chico has also been envisaged to facilitate the participation of Mexican and foreign researchers and students.

Progress so far includes the sale of 44 permits to hunt white-tailed deer in the 2003-2006 period, generating a total income of USD 66,000 (Rosas-Rosas and Val-

Pumas (*Puma concolor*) coexist with jaguars in northeastern Sonora and are more abundant in the region. Both species are subject to predator control, as they are considered a threat to livestock.

Photo: Octavio C. Rosas Rosas (with camera-trap)

Jaguars (*Panthera onca*) is uncommon in northeastern Sonora. Unless a joint effort is made by landowners, educational and research institutions and the state and federal government, its future will be uncertain in this region at the northern limit of its range.

Photo: Octavio C. Rosas Rosas (with camera-trap) déz, 2010). The funds are aimed at improving livestock farming operations to minimize possible conflicts with predators and equipping ranches to receive tourists interested in hunting or alternative activities and researchers. The creation of jaguar conservation unit has the goal of establishing a long-term sustainable conservation culture in the municipality of Nácori Chico, Sonora.

Acknowledgements

We would like to thank the Wildlife Conservation Society Jaguar Conservation Program, the Consejo Nacional de Ciencia y Teconología (CONACyT-Mexico), the New Mexico Cooperative Wildlife Research Unit-USGS, the Departments of Biology and Wildlife Sciences of the New Mexico State University, the Summerlee Foundation, the National Park Service, the U.S. Fish and Wildlife Service and all the volunteers for their great support in the development of this project.

STATUS OF JAGUARS IN THE STATE OF TAMAULIPAS

Arturo Caso

Resumen
En Tamaulipas aún existen poblaciones de jaguar, pero debido a factores antropogénicos como la destrucción del hábitat y la cacería furtiva, la distribución de este felino se ha visto seriamente afectada. Durante 12 años se recopilaron datos de campo sobre la presencia del jaguar en el estado, mediante entrevistas, encuestas y visitas de campo. Para determinar su situación actual se realizó un análisis del hábitat disponible del jaguar utilizando imágenes LANDSAT. Se estimó una superficie de 1,110,878 ha de hábitat disponible para el jaguar en todo el estado de Tamaulipas, siendo la Sierra Madre Oriental y la Sierra de Tamaulipas los sitios con mayor superficie de hábitat. Esto indica que aún es posible mantener estas poblaciones a largo plazo.

Abstract
In Tamaulipas, jaguar populations still remain. However, due to anthropogenic factors such as habitat loss and by poaching, the distribution of this felid has been affected. For twelve years, data about jaguar presence on different locations within the State, have been recorded through interviews and surveys to local people and field visits. Recently, available habitat analysis was conducted using LANDSAT imagery, to identify the remaining locations with the largest amount of jaguar habitat. An area of available jaguar habitat for the state of Tamaulipas was estimated of about 1,110,878 ha, being the Sierra Madre Oriental and the Sierra of Tamaulipas the areas with the greatest habitat availability. This suggests that this jaguar population has some chances for long term persistence.

Introduction
Jaguar populations still remain in Tamaulipas. However, they are affected by several factors, such as habitat destruction and modification due to agriculture, and poaching. In areas with livestock farming, jaguars have been driven to attack livestock because of the pressure of humans on natural prey, such as deer or peccary, or injuries that make hunting difficult. This has been recorded on several locations in their range (Rabinowitz, 1986). The result of these events is usually the death of one or more jaguars, since lethal control is not targeted to problem individuals (Caso, 1993). This has led to a dramatic decline in jaguar populations over the last 30 years, reducing the species' original range by almost 1,000 km towards the south (Sunquist and Sunquist, 2002; Swank and Teer, 1989).

Jaguars are at the top of the food chain and require large stretches of natural habitat to survive. They should be considered as an indicator of ecosystem status

(Caso, 1994; Miller *et al.*, 2001). Successful conservation of jaguars indirectly protects other wild animal species of great importance –endangered species such as the ocelot (*Leopardus pardalis*), game species such as the white-tailed deer (*Odocoileus virginianus*), or species that attract tourism, such as the yellow-crowned Amazon (*Amazona ochrocephala*). In Tamaulipas, these species share their range with the jaguar and are also suffering from habitat destruction.

Although the jaguar still occurred in the state of Texas, USA, in the 1940s, the last confirmed report of the species was in 1946, when a jaguar was hunted 10 km south of San Benito, Texas (Taylor, 1947). There are no recent records of the jaguar in Texas, which indicates that the northernmost part of its range is now the Sierra Madre Oriental in Tamaulipas. Leopold (1959) and Alvarez (1963) mentioned the distribution of the species in the center and all along the coastal plain of the state of Tamaulipas. More recent publications set the northeastern limit of its range in the states of Nuevo León, Coahuila and Tamaulipas (Brown and López-González, 2001; Neff, 1982; Rosas-Rosas and López-Soto, 2002; Sunquist and Sunquist, 2002). Tamaulipas was historically an area where jaguars were hunted, which is why most of the little information available comes from hunters. Therefore, the aim of this study was to document current or recent jaguar presence in Tamaulipas and determine how much habitat is still available for the species.

Methods

To carry out this study, we used data obtained during 12 years of fieldwork in the state of Tamaulipas through interviews, surveys sampling and field trips (Appendix 1). We took measurements and other data from hunted specimens. To estimate the amount of suitable jaguar habitat, we considered the home range reported for Mexico and Central America (Ceballos *et al.*, 2002; Rabinowitz, 1986). We included pine-oak woodlands in our analysis, as they have been reported to be used by jaguars (Brown and López-González, 2002; Leopold, 1959). Some areas such as the Sierra de San Carlos were not included in the analysis because in an earlier visit no locals reported seeing any jaguars, tracks or scats, or mentioned any losses of livestock attributed to jaguars. The general analysis of jaguar habitat was based on a 2000 ETM-7 LANDSAT image of the state of Tamaulipas. We used ArcGis 9.0 and ERDAS IMAGINE 8.7 software to classify the areas according to their vegetation cover and refractive potential.

To classify the truthfulness of records, we used the criteria set by Tewes and Everett (1982) and only considered Class I sightings, which imply direct possession or observation of the animal by the authors, possession of the animal or skin by the observer, photographs of the animal taken in situ (e.g., with a remote camera) or capture of the animal.

Results and discussion

Ten recent (<15 years) Class I records of the jaguar were obtained in Tamaulipas, in the following municipalities: Aldama, Gómez Farias, González, Hidalgo, Jaumave, Ocampo, Soto la Marina and Villa de Casas (Table 1). Observations and habitat analysis with ArcGis software led to estimating a total surface of 1,110,878 ha of suitable jaguar habitat in the state of Tamaulipas (Table 2; Figure 1).

The area estimated to be suitable jaguar habitat in Tamaulipas must be considered with caution, as the different habitat types considered in the satellite images must be validated in the field. Besides, a greater number of records is necessary to increase accuracy. In spite of these limitations, the area estimated in this study for the Sierra de Tamaulipas is consistent with other studies carried out in the same area (Ortega-Huerta and Medley, 1999). Based on the available habitat and records of predation on livestock, there is likely to be a considerable population of jaguars in this mountain range, now isolated from the Sierra Madre Oriental.

Jaguar habitat in Tamaulipas has decreased compared to reports on its distribution in the past (Alvarez, 1963; Leopold, 1959). One of the factors directly determining jaguar habitat loss is the deforestation due to charcoal production. Poaching also exerts pressure on existing jaguar populations, as shown by the fact that half of the jaguar records in the state were skins of illegally hunted animals.

Table 1. Recent jaguar records in the state of Tamaulipas

No	Year	Site	Municipality	Record	Topography
1	1991	E. Los Caballos	Hidalgo	Skin of hunted animal	Sierra Madre Oriental
2	1992	R. La Lajilla	V. de Casas	Tracks, scats	Sierra de Tamaulipas
3	1993	R. Miradores	S. la Marina	Skin of hunted animal	Sierra de Tamaulipas
4	1993	R. El Porvenir	S. la Marina	Capture	Sierra de Tamaulipas
5	1995	E. Noche Buena	S. la Marina	Skin of hunted animal	Sierra de Maratines
6	2001	E. San Vicente	Jaumave	Livestock killed by jaguar	Sierra Madre Oriental
7	2001	E. Ricardo Flores Magón I	Ocampo	Skin of hunted animal	Sierra Madre Oriental
8	2003	Gómez Farías	Gómez Farías	Direct observation	Sierra Made Oriental
9	2003	R. Almagre	González	Skin of hunted animal	Sierra de Tamaulipas
10	2004	R. Balcones	Aldama	Capture and photograph	Sierra de Tamaulipas

E. = Ejido; R. = Ranch

Table 2. Regions and surface available with jaguar habitat in the state of Tamaulipas

Regions	Surface (ha)
Sierra Madre Oriental	729,812
Sierra de Tamaulipas	366,493
Sierra de Maratines	14,573
Total	1,110,878

The three areas where jaguars are present are separated and probably isolated from each other. The distance between them is at least 50 km of land that has been cleared for agriculture, with several highways. This represents a major barrier for the jaguar and suggests that the populations are isolated.

In the Sierra Madre Oriental, most records were obtained in the south, in the municipalities of Llera, Ocampo and Jaumave. There was one direct sighting in El Cielo Biosphere Reserve, in the Gómez Farías region. However, jaguar presence is sporadic in that area and locals complain more about livestock losses caused by black bear (*Ursus americanus*) than by large felids (puma and jaguar). The limited number of jaguar records in this region is probably also linked to the low abundance of potential prey such as the collared peccary (*Tayassu tajacu*), white-nosed coati (*Nasua*

Figure 1. Current range of jaguars in the state of Tamaulipas.

narica), and white-tailed deer (*Odocoileus virginianus*), which are hunted by locals (Aranda, 1994). The Sierra Madre Oriental in Tamaulipas extends southwards to San Luis Potosí, where there are no verified reports . However, the findings show that there is suitable jaguar habitat, so there may be a jaguar population in thas region as well. In the northwest, this mountain range is connected to the Sierra Plegada in Nuevo León, where jaguar presence has been recorded (Rosas-Rosas and López-Soto, 2002).

Jaguar conservation in Tamaulipas requires accurately determining its current status, since there are no data about population size or ecology. It is therefore urgent to conduct studies on the status of this species and to carry out conservation actions to ensure the future of this population.

Figure 2. The mountain ranges in Tamaulipas contain the northernmost jaguar populations on the side of the Gulf of Mexico. Jaguar has serious conflicts in Tamaulipas due to livestock predation.
Photo: Arturo Caso

Appendix 1
Form used to record jaguar presence in interviews

Record of death caused by a jaguar
No._________ Date of the attack ___/___/____

Name of rach____

Name of ower____

1) What animal was killed?
a) calf b) young bull or heifer c) cow orbull d) horse e)other_______

2) Approximate age of the animal killed (months; years)____________________

3) Vegetation type where the carcass was found___________________________

4) How far was the animal dragged from the place where it was attacked (approximately)?____

5) How long after the attack was the carcass foud?________________________

6) The carcass was found (mark the appropriate answers with a cross)
- a) Only dead (not eaten)
- b) If eaten, what part was eaten?______________________________
- c) It was covered with leaves and dirt
- d) It had blood (and marks of bites) on its throat
- e) It had blood (and marks of bites) on its neck or skull
- f) If the cat was seen eating the prey, what species was it?__________
- g) Were any tracks found?_______

7) This attack represents the (number)_______ of my animals killed by cats this year.

8) Do cats cause problems to your livestock all year round? Yes ____ no_____. If the answer is yes, how many animals do you think are killed by big cats on your property every year?_______ What kind of cat –puma or jaguar– do you think causes the damage?_____________________

9) Have you used any methods to control big cats in your property? Yes _______ no_______. If the answer is yes, please explain______________________________

10) Would you like to find out more about the choices available to solve the problem of livestock losses caused by big cats? Yes _______ no________

DISTRIBUTION AND STATUS OF JAGUARS IN WESTERN MEXICO

Rodrigo Núñez Pérez

Resumen

El jaguar habita un paisaje modificado y dominado por el hombre en el occidente de México. El hábitat se ha reducido en extensión, está fragmentado y continúa sufriendo fuerte presión para dar paso al desarrollo y a la frontera agrícola-ganadera. El jaguar ha desaparecido de grandes áreas de su área de distribución, pero se desconoce su situación actual. Mediante el empleo de entrevistas, registros en campo y revisión de cartas topográficas y el uso del del Inventario Nacional Forestal, se determinó la distribución potencial y áreas críticas para el jaguar en los estados de Nayarit, Jalisco, Colima y Michoacán. Para conocer la percepción y aceptación social sobre la conservación del jaguar se realizaron entrevistas en localidades donde el jaguar está presente. Los resultados indican que el jaguar aún ocupa gran parte de su rango de distribución histórico pero con poblaciones fragmentadas y en bajas densidades. Se encuentra mejor representado en las selvas de Jalisco y Nayarit, mientras que, en Colima y Michoacán son escasos los registros. Seis áreas fueron identificadas como prioritarias (3 en Jalisco, 3 en Nayarit). En la mayor parte de las áreas donde se identificó la presencia del jaguar existía el conflicto con los ganaderos. En general, los pobladores están de acuerdo que se conserve al jaguar, siempre y cuando se atienda la problemática que existe con los felinos que depredan ganado.

Palabras clave: occidente de Mexico, hábitat potencial, áreas prioritarias, percepción social.

Summary

Jaguars inhabit a modified and human dominated landscape in western Mexico. Its habitat has been reduced and fragmented, and the pressure from agriculture and cattle ranching continues. Jaguars has been extirpated from large areas within its historic range, but its current situation is unknown. Using interviews, field records and topographic maps, and the National Forest Inventory, the potential distribution and critical areas for the species in Nayarit, Jalisco, Colima and Michoacán states was determined. In order to know the perception and social acceptance of jaguar conservation, interviews were conducted in areas where jaguars are known to be present. The results indicate that jaguars occupies a large portion of the historical range but with fragmented populations and in low population densities. It is better represented in the tropical forests of Jalisco and Nayarit, while in Colima and Michoacán the records are scarce. Six priority areas were identified (3 in Jalisco and 3 in Nayarit). In most of these areas there were conflicts with cattle ranchers. In general, local people agree to protect jaguars if the problems of livestock predation are solved.

Key words: West Mexico, potential jaguar habitat, priority areas, social perception.

Introduction

In Mexico, jaguars are a protected species listed as endangered (Semarnat, 2002). In 1987, it was considered that jaguar populations in Mexico had declined by as much as 65% (Swank and Teer, 1989). However, the distribution and current conservation status of the species are unknown in most of the country. Habitat loss has been one of the leading causes of the disappearance of large carnivores (Nowell and Jackson, 1996), and jaguars are no exception.

In western Mexico, jaguars used to be present in the Pacific coastal lowlands, the Sierra Madre del Sur and part of the Sierra Madre Occidental (Ceballos and Oliva, 2005; Hall, 1981; Leopold, 2000). Although the abundance of jaguars in those areas is not known, the species is considered to have been abundant in the wetlands and forests of Nayarit and Jalisco, according to reports by hunters and some authors (Carmony, 1995; Leopold, 2000).

For a long time, the rugged terrain, dense vegetation and lack of roads protected the jaguar from human activities. Yet, this changed in the 1970s with the construction of federal coastal road No. 200. Changes in land use accelerated and jaguar habitat was transformed and fragmented. Although jaguar populations in this part of the country were considered to be declining, fragmented and to have low densities in 1987 (Swank and Teer, 1989), there were still opportunities to conserve the species if the existing threats –deforestation and persecution of jaguars– are eliminated (Navarro, 1993).

The Wildlife Conservation Society considers western Mexico as a Type 1 jaguar conservation unit (JCU 3) which may contain 500 breeding individuals (Marieb, 2005). Although jaguars have traditionally been associated to dense tropical vegetation (Chávez et al., 2005; Guggissber, 1975; Seymour, 1989), they have been observed in temperate forests and semi-arid regions (Brown and López-González, 2001; Núñez, 2007; Monroy *et al.*, 2005, in press). In spite of the significant changes in the landscape caused by human activities, the jaguar is a versatile species and can be found in areas with a certain degree of disturbance (Brown and López-González, 2001; Sanderson *et al.*, 2002; Núñez, 2007). Along the coast of Jalisco and Nayarit, the jaguar coexists and continually interacts with humans. In fact, the dramatic increase in the human population of coastal areas in the last decade (Conapo, 2000) has already put greater pressure on jaguar populations. In order to implement an appropriate and practical conservation strategy, it is necessary to determine the status of the species and identify where its populations occur (Bailey, 1994).

According to the National Forest Inventory, western Mexico no longer contains large areas of well-conserved forests. The landscape is fragmented and subjected to different degrees of disturbance. In this part of Mexico, jaguar conservation must be compatible with human activities. Conservation of large carnivores that coexist with humans implies broad social participation. The acceptance of such participation in conservation activities will be key in successfully protecting the species (Naughton-Treves *et al*., 2003; Oli *et al*., 1994). The coast of Jalisco and Nayarit is currently under great pressure by the construction of major tourist resorts and associated infrastructure, such as roads and freeways. In Jalisco, most coastal land has been privatized in the last few years (Del Castillo, 2007) and some activities are already having a negative impact on jaguar habitat around the Chamela-Cuixmala Biosphere Reserve (RBCC; Instituto de Biología, 2007). Moreover, the Mexican Federal Electricity Commission (CFE) did not report jaguar presence in its environmental impact statements for the series of hydroelectric dams it is building along the Santiago river, with a total water surface that is 150 km long so far. The artificial lakes formed undoubtedly displaced an unknown number of jaguars, formed a barrier to dispersal and fragmented the local population, one of the most important ones because of the large amount of habitat available.

It is important to determine the current status of jaguars and identify key conservation areas. This will be needed to design a management and/or recovery plan that matches the current situation, and to make recommendations and take mitigation measures to reduce the impact of human activities on jaguar populations. Livestock farmers and rural people are quite familiar with jaguars in the states of Jalisco, Nayarit and Michoacán, and the presence or absence of the species is usually reported in specific areas. Few studies have attempted to determine the status of jaguars in the region. In 1995, an informal data collection initiative was set up to obtain information on jaguars presence along the coast of Jalisco, Colima and Michoacán, in parallel to the Jaguar Project carried out in the RBCC.

This paper presents and discusses the results of the study carried out between 2005 and 2007 to determine the distribution of jaguars and its current status in western Mexico and identify key conservation areas in the states of Nayarit, Jalisco, Colima and Michoacán.

Study area

The study area basically comprises the coast and coastal mountain ranges of the states of Nayarit, Jalisco, Colima and Michoacán. There are many towns and villages scattered across this area, which includes 4 physiographic regions: Sierra Madre Occidental, Neovolcanic Belt, Northwest Coastal Plain and Sierra Madre del Sur. The area has two basic climate types: tropical sub-humid and temperate sub-humid (Challenger, 1998). Elevation ranges from sea level to 2500 masl. The most important vegetation types are tropical deciduous forest, semi-evergreen forest, oak and oak-pine forest, mangrove and secondary grassland (Rzedowski, 1994). The landscape is dominated by land that has been cleared for livestock farming, and there are few large stretches of undisturbed native vegetation. Most original vegetation cover is fragmented and subjected to some degree of disturbance, and large areas have been totally cleared for agriculture. Eight priority conservation areas identified by the federal government's National Commission on Biodiversity (Conabio) are totally or partially located within the study area: No. 59-Cuenca del Río Jesús María, No. 60-Sierra de los Huicholes, No. 61-Marismas Nacionales, No. 62-Sierra de Vallejo-Río Ameca, No. 63-Chamela-Cabo Corrientes, No. 64-Manantlán-Nevado de Colima, No. 115-Sierra de Coalcoman, and No. 116-Infiernillo (Arriaga *et al.*, 2000).

The most common human activities in rural areas are agriculture, extensive livestock farming, logging, fishing and tourism (Coplade, 2005; Seplan, 2001). Most of the seasonal and oak forests in Jalisco and Nayarit are invaded by cattle. Although there is also extensive livestock farming in the state of Michoacán, although it is not as important as in Nayarit and Jalisco; the latter is the second largest livestock producer in Mexico. Three large indigenous communities live in the study area –the Nahua on the coast of Michoacán and the Cora and Huichol in the northeast of Nayarit (Conabio, 2006), as well as some Nahua groups in the south of Jalisco.

Methods

In order to find the possible areas where jaguars of the RBCC may disperse and areas where jaguars are present in the state of Jalisco, we looked for records and conducted interviews occasionally from 1995 onwards. The interviews showed two main topics: the presence of the jaguar and conflict due to jaguar predation on livestock. In July and August of 2005 and 2006, livestock farmers, ranch owners and hunters in over 35 sites were surveyed with open and closed interviews (Karanth and Nichols, 2000, Medellín *et al.*, 2006; Rabinowitz, 1997) to learn about the distribution of jaguars and obtain physical records and feedback about the perception and attitude of these groups regarding jaguar conservation and conflict due to livestock predation. Additionally, open interviews were conducted with veterinarians, forestry officials, researchers and government officials of Semarnat, Profepa and Conanp in each of the states involved in fieldwork.

Fieldwork involved looking for records such as skulls, skins, photographs and tracks; camera traps were used in 5 sites. Reports of predation on livestock were one of the most reliable indicators of jaguar presence because ranchers and/or cowboys are continually present in the field and have experience in recognizing tracks of felids and marks on carcasses. Reports of livestock predation were dealt with by the author and/or staff of Semarnat and Profepa in Nayarit and Jalisco. We visited 16 sites in Jalisco, 11 in Nayarit and 4 in Michoacán, where livestock predation and/or jaguar sightings were reported. Camera traps were placed in 5 sites to record jaguar presence: 2 sites in Jalisco (n=3 and 5 stations, 2 in Nayarit (n=4 and 2 stations) and 1 in the state of Michoacán (n=1 station). Eleven groups of active community observers cooperated in these activities-interviews and field visits. Records such as tracks and camera traps were georeferenced with a Global Positioning System receiver (GPS, Garmin, USA), and the features of the relevant habitat were recorded.

We determined the potential area of distribution and the most important areas for conservation based on the interviews, human presence, referenced records and type of habitat available. Given that habitat characterization is mainly based on vegetation (Ojasti, 2000), 1:250,000 vegetation maps (INEGI, 1996) and the 2000 National Forest Inventory were used to identify critical areas. Potential habitat within protected areas in the region was determined by using Series III vegetation maps (INEGI).

To obtain feedback on the social perception and attitudes of communities towards jaguar conservation and conflict caused by predation on livestock, intensive interviews were conducted in the summers of 2005 and 2006 in 3 different areas with frequent reports of sightings of jaguars and their tracks, and reports of livestock predation. We interviewed 120 ejidatarios (peasants with communal lands) from Sierra de Vallejo-Zapotan in Nayarit, 20 from Cabo Corrientes in Jalisco, and 40 members of agrarian communities of the Pomaro indigenous community in Michoacán. The interviews included 24 questions on these people's perception about the historical and current abundance and presence of jaguars, the conflict caused by livestock predation and their attitudes towards the conservation of the species and its habitat.

Results and discussion

This study is still under way, so results on jaguar distribution are preliminary; in some areas, jaguar presence has not been confirmed but there are reliable reports about its presence.

Distribution

Jaguars are well known in rural areas of Jalisco and Nayarit, but there is little evidence of its presence in rural communities in Michoacán and Colima. In Jalisco and Nayarit, jaguar is present in much of its original range, although populations are fragmented and dispersed; in some areas, population density is low or the presence of the species is only temporary. According to the interviews, jaguar has been extirpated or is only occasionally present in Colima and Michoacán. In Jalisco and Nayarit, 75% of records were associated to tropical rainforest and semi-evergreen forest, 12.5% were associated to oak forest and 12.5% were associated to wetlands. In Michoacán, the most recent records were taken in the tropical deciduous forest and oak forests. Records corresponded to an elevation range between 0 and 1400 masl, although jaguar presence has been reported at elevations greater than 2000 masl. Six critical areas for jaguar conservation were identified, 3 in Jalisco and 3 Nayarit. In Michoacán, it was suggested that the most important areas may be in the municipalities of Aquila and Arteaga (Figure 1), although no recent physical records of jaguar presence are known to exist.

Nayarit

Jaguar records were recorded in 26 sites, in 18 out of the 22 municipalities of the state. Most records (65%) were obtained in areas with semi-evergreen forest and tropical deciduous forest, followed by mangroves (25%, in Marismas Nacionales), and the remaining 10% were obtained in oak forests.

This suggests that jaguar still occupies most of its original range in the state (Figure 1); however, its habitat is fragmented. Nayarit is believed to contain between 9,000 and 11,000 km^2 of potential jaguar habitat. The addition of several sections of the Basin of Irrigation District 043 (CADNR 043) to the protected area system –Aguamilpa, Sierra de los Huicholes and Vallejo-Ameca– means that 450,000 ha of suitable jaguar habitat are now protected in different parts of the state. Although the region with the highest number of reports on jaguar presence is the southern coast of the state and the Marismas Nacionales Fauna and Flora Protection Area, information is biased towards these regions because they are more accessible and there are more people working there. In the Sierra region there are few records of jaguar presence because access is difficult. In the neighboring state of Durango, just on the other side of the state boundary, Dr Jorge Servín (pers. comm.) recorded jaguar presence around small creeks with semi-evergreen forest near the village of San José Peyotán (municipality of El Nayar) and near El Cajón dam. In the municipality of Santa María del Oro, in the same region, a calf was killed by a jaguar in a landscape dominated by pine-oak forest and secondary grassland, with some tropical deciduous forest around small creeks.

Based on the quality and type of vegetation and human presence, three priority areas for jaguar conservation were identified in the state:

a) Marismas Nacionales: These wetlands were listed in the RAMSAR convention for the conservation of wetlands in 1995 and are in the process of being declared a protected area. The part located in Nayarit comprises 130,000 ha. Vegetation is mostly represented by mangroves (60,000 ha) in the tropical deciduous forest and

Figure 1. Potential range of jaguars in western Mexico. Priority areas for jaguar conservation: 1) Sierra de Nayar; 2) Marismas Nacionales; 3) Sierra de Vallejo-Zapotan; 4) La Yesca, 5) Cabo Corrientes- Tomatlan, 6) Chamela-Cuixmala, and 7) Sierra de Manantlán-Cacoma.

by halophytic vegetation (UAN, 2004). Wetlands in the state of Nayarit are gradually becoming isolated due to deforestation. In this area, the annual deforestation rate is 2.7% for the tropical deciduous forest, and 0.8% for mangroves (Berlanga *et al.*, 2004; Berlanga and Luna, 2007). A narrow corridor of mangroves along the coast connects the region to the wetlands in Sinaloa, the forest areas of the "Pie de la Sierra" region and to rocky volcanic areas associated to the Cerro de San Juan volcano in the south. According to reports by fishermen and farmers, reptiles (turtles) and medium-sized mammals such as coatis and raccoons are important in the jaguar's diet.

b) Sierra de Vallejo-Sierra Zapotan: According to the records, jaguars were heavily hunted in this area in the past and was still hunted illegally until a couple of years ago, mainly by hunters from Guadalajara. Information obtained by camera trapping shows that the jaguar is still common in these mountain ranges. Seven camera stations were placed in five sites for one month, for a total of 240 trap nights. No jaguars were recorded in two sites, and six different jaguars were recorded in the remaining three sites. Sierra de Vallejo-Zapotan is covered with semi-evergreen forest, tropical deciduous forest, secondary grassland and patches of oak-pine forest (Conanp, 2005). The terrain is rugged and there is little availability of natural prey due to intense poaching and a high presence of livestock. The underbrush has disappeared in large areas because of overgrazing. This area covers a surface of about 100,000 ha and is connected to the mountain ranges of the north of Jalisco. It is one of the last large patches of semi-evergreen forest that remain in this part of the country (more than 1,500 km^2; Arriaga *et al.*, 2000). The Vallejo-Ameca portion of the CADNR 043 conservation unit is attached to the Sierra de Vallejo. It comprises 350,000 ha, out of which 170,000 ha are potential jaguar habitat –mainly tropical deciduous forest and semi-evergreen deciduous forest– (Table 1, Figures 1 and 2). The Sierra de Vallejo-Zapotan may lose connectivity with the rest of the state unless appropriate mitigation measures are taken in the construction of the road from Jala to Las Varas (Semarnat, 2007).

Figure 2. Protected areas in western Mexico: A) Marismas Nacionales; B) Sierra de Vallejo; C) Chamela-Cuixmala; D) Sierra de Manantlán Biosphere Reserve; E) Zicuiran-Infiernillo Biosphere Reserve; F) Basin of Irrigation District 043 Vallejo-Ameca, and G) Basin of Irrigation District 043 Aguamilpa.

Potential range in Jalisco
Potential range in Michoacán
Protected areas

c) Region of La Sierra: In the municipalities of El Nayar and La Yesca, the dominant vegetation is pine-oak forests and secondary grassland, and there is tropical vegetation around small creeks. This region has large stretches of vegetation with a low level of disturbance and the lowest population density of the state 4.2 people/ km^2 (COPLADENAY, 2003). In the low part of the mountain range there are areas of semi-evergreen forest and tropical deciduous forest where jaguar presence has been recorded, near the Aguamilpa dam and on Picacho Mountain. In July 2007, a jaguar female and two cubs were found in a canyon close to El Cajón hydroelectric dam (pers. obs.). The size of this area –more than 1,000 km^2– makes it highly important for the conservation of the species. Although the landscape is dominated by oak forests and there are large areas of secondary grassland, the low human presence, difficult access and rugged terrain may contribute to the conservation of the jaguar. The Aguamilpa and Sierra de los Huicholes sections of CADNR 043 represent 300,000 ha of potential jaguar habitat. A fourth area in the eastern part of the state in La Yesca region may be important for jaguars, but large areas of tropical deciduous forest have been transformed into grassland. Small creeks that still have some elements of tropical vegetation around them are of great importance in these areas. Although the mountain ranges of El Nayar and La Yesca are still interconnected, they have lost connectivity with the south of the state. The construction of the Aguamilpa-La Yesca series of hydroelectric dams in Nayarit and Jalisco at their maximum capacity may create a barrier for the dispersal of individuals. Besides, the construction of the road connecting Tepic with the state of Zacatecas will imply paving 64 km; the paved road will reach La Mesa del Nayar, which may accelerate fragmentation and loss of connectivity.

Table 1. Potential jaguar habitat in protected areas (PA) of western Mexico

	Category	Total surface PA (ha)	Approx. potential jaguar habitat	Dominant vegetation in PA
Chamela-Cuixmala	BR	13,000	12,000	SB
Sierra de Manantlán	BR	140,000	60,000	BQ, BQP, SM
Marismas Nacionales	APFF*	110,000	60,000	VM, SB.VH
Sierra de Vallejo	BR**	70,000	45,000	SM, SB
Zicuiran-Infiernillo	BR	262,000	146,000	SB, SE
Aguamilpa	CDR 43	315,000	165,965	SB, BQ
Sierra Vallejo-Ameca	CDR 43	352,000	171,213	SB, SM, BQ
Sierra Los Huicholes	CDR 43	195,000	122,850	BQ, SB

* BR pending decree
** State BR pending decree
BR: Biosphere Reserve
APFF: Fauna and Flora Protection Area
CDR: Basin of irrigation district
SB: tropical deciduous forest; BQ: oak forest; BQP: pine-oak forest; SM: semi-evergreen forest; SE: thorn forest; VM: mangroves; VH: salt-adapted vegetation

Jalisco

In Jalisco, it was estimated that jaguars may still occupy about 8,000 km^2 of its original range. There are published records of jaguar presence mainly in coastal municipalities and mountain ranges near the coast such as the sierras of Cacoma, Manantlán and El Tuito (Ceballos and Miranda, 2000; Conanp, 2000; Gallo, 1989; Núñez, 2006; Núñez *et al.*,1981). No data are available for the Sierra Madre Occidental. Although jaguars have disappeared from large stretches of land cleared of its original vegetation and subjected to intense human activity, there is still connectivity between the different forests where jaguars are present. Jaguar presence was identified in 22 sites. Sixty percent of records came from areas with tropical deciduous forest, 25% came from areas with semi-evergreen forest and 15% came from pine-oak forests. Seventy percent of records were obtained in areas with some degree of disturbance, such as secondary grassland. The distribution of jaguar are concentrated in the forests and mountain ranges of the municipalities of La Huerta, Cihuatlan, Tomatlan, Cabo Corrientes, Puerto Vallarta, Casimiro Castillo and Talpa. According to livestock farmers and Huichol indigenous people, jaguar still occurs around the small creeks of the Sierra Madre Occidental and one jaguar was killed in mid 2006 because it had attacked livestock. In the range of the jaguar in Jalisco, two areas are considered essential to conserve wildlife and maintain corridors because of their size and the quality of their plant cover: the San Sebastián- Cabo Corrientes and Cabo Corrientes-Tomatlán corridors (Curiel and Ramos, 2003).

Based on habitat availability, 3 priority areas for jaguar conservation were identified:

a) Cabo Corrientes-Ameca: A large area with semi-evergreen forest, tropical deciduous forest and pine-oak forest, which is considered very important because of its size and quality (Arriaga *et al.*, 2000; Curiel and Ramos, 2003). It is connected to the mountain ranges of the south of Nayarit (Vallejo-Zapotan) and the municipality of Tomatlán, Jalisco. Part of the CADNR 043 Sierra Vallejo-Río Ameca (350,000 ha) is located in this region, and about half of its plant cover (170,000 ha) is favorable to jaguar presence. Cabo Corrientes has few paved roads, with the exception of federal coastal road No. 200. In the first semester of 2007, 3 camera trap stations were placed and jaguar and puma presence was recorded in several sites in the region. Photo records show that jaguars can use disturbed areas, but more fieldwork is necessary. The initiative of protecting some areas of this region through the creation of the biosphere reserve in the north coast of Jalisco has been given a new impulse, although it has not taken place yet for different reasons (Figures 1 and 2). In the municipality of Cabo Corrientes, extensive livestock farming is a deeply rooted activity and complaints of livestock predation are frequent.

b) Chamela-Cuixmala-Tomatlán: This region includes the Chamela-Cuixmala Biosphere Reserve (RBCC), which protects 13,000 ha; an increase in the number of jaguars has been observed over the last 10 years (Núñez, 2006b). This region is connected to the forests of Tomatlán and the south of the state. However, the recent construction of roads and tourist developments (Semarnat, 2005; Instituto de Biología-UNAM, 2007) is compromising jaguar conservation in this area and connectivity with the forests of the municipality of Tomatlán (Figure 2). There are more than 10,000 ha of natural vegetation in adjoining areas of the biosphere reserve where jaguars still occurs, as well as vegetation corridors that maintain connectivity with the forests of the municipality of Tomatlán and the state of Colima to the south.

c) Sierras Cacoma-Manantlán: Jaguar presence and attacks on livestock are often reported in these mountain ranges. The jaguar is present in Manantlán Biosphere Reserve (RBSM; Conanp, 2000). The Reserve covers 120,000 ha and includes Cerro Grande in Colima. Jaguars have been recorded mainly in areas with tropical deciduous forest, semi-evergreen forest and oak forests in areas in the south of the RBSM and Cerro Grande with coastal orientation. The Reserve contains about 60,000 hectares of suitable jaguar habitat (Table 1). The presence of the species has recently been recorded in the region, but there seem to be few individuals, dispersed in low areas (Aranda, pers. comm). The mountain ranges of Manantlán, Cacoma, Perote and Mamey can be a refuge for the jaguar if the existing threats –reduction of natural prey, destruction of the forest and hunting– are eliminated. This area is connected to the north of Colima and the RBCC by vegetation corridors. Habitat fragmentation and the construction of new roads (Semarnat, 2005) threaten the connectivity between the two biosphere reserves.

Colima

A male jaguar was hunted in the municipality of Manzanillo, Colima in 2006. Jaguar presence is reported in the mountain ranges of the north of the state that are adjacent to Jalisco, including the RBSM (Figure 1). This area provides shelter to the jaguar because of the rugged terrain and the existence of habitat. Jaguar presence is also reported around the small creeks of Cerro Grande in the RBSM. The Natural History Museum of Los Angeles County has 3 jaguar specimens that were collected in El Terrero, in Cerro Grande, Colima, in the late 1960s. The jaguar can thrive if it is well protected in the Sierras de Perote and Mamey, north of the state and next to Jalisco. Some hunters claim to have seen jaguar tracks in the tropical deciduous forest of areas adjacent to the state of Michoacán, but jaguar presence has not been confirmed. There are jaguar records in Michoacán. The forests of the north and south of the state are separated by agricultural land and the Colima-Manzanillo freeway. Some very narrow ravines cross this area below the Guadalajara-Manzanillo highway, and may act as wildlife corridors, but they are very narrow.

Michoacán

Very little is known about the current status of jaguars in the state of Michoacán. Historically, jaguars occupied the mixed forests and other forest types of the coast and the Sierra Madre del Sur (Government of the state of Michoacán, 1974). Brand (1961) reported jaguar presence in pine and oak forests near Coalcomán. The most recent record (tracks) was obtained by Núñez *et al.* in May 2007, in a coastal Nahua indigenous community. Previously, Gallo Reynoso (pers. comm.) found a jaguar skin in the municipality of Arteaga in 1987, but the place where it was hunted is unknown. Between 1993 and 1995, a male jaguar was killed near Motín del Oro, in the municipality of Aquila. According to the size of the skull and the state of the canines, it was a subadult individual. A skull of a male jaguar killed in 1980 near Chuta, in the municipality of Lázaro Cárdenas, was also inspected. Recent reports from 2005 and 2006 mention that a male jaguar was killed in a coastal indigenous community as a reprisal for killing a horse. A person also reported having captured a jaguar cub in a place between the boundaries of the municipalities of Coalcomán and Aquila (oak-pine forests) and the death of the cub a few weeks later. Jaguar presence has also been reported in the most inaccessible areas in the municipality of Coahuayana, in areas adjacent to Colima. The coast of Michoacán is mainly covered by tropical deciduous forest. In spite of being relatively inaccessible, it is fragmented and the vegetation has some degree of disturbance (COFOM, 2001). The complex topography, habitat availability, and low human activity in this part of the state may still provide a chance for the conservation and recovery of jaguars. The jaguar seems to be uncommon in the state, or less known than in Jalisco and Nayarit, but fieldwork is needed in much of its potential range to confirm the presence and status of jaguars and also to implement conservation measures in this state.

Jaguar presence has not been confirmed in the regions of Tierra Caliente and the Balsas Depression, where there is tropical deciduous forest and thorn forest. In 1987, however, Gallo (1989) found two jaguar skins in Ciudad Altamirano, Guerrero, in the intersection of the Balsas and Cutzamala rivers, and adjacent to the municipality of San Lucas Michoacán in the Tierra Caliente region. In 2004, the first jaguar record for State of Mexico (Monroy *et al.*, 2005; this volume) was obtained near the boundary with Michoacán. It was a photograph of an individual taken in the Sierra de Nanchititla (1,800 masl), in the municipality of Tejupilco, next to the municipalities of Tiquicheo and Tuzantla, Michoacán. The site where the photograph was taken is 20 km from the boundary with Michoacán and 70 km north east of Ciudad Altamirano. This makes it logical to consider that there may be jaguar individuals in some areas of Tierra Caliente, especially in tributaries of the Tuzantla and Balsas rivers with little human presence. After the search for physical records in Michoacán began in 2005, reports of jaguar presence and livestock depredation were obtained in the municipalities of Arteaga and Huacana, but it was not possible to verify them. In Arteaga, jaguar records are associated to the transition area between the tropical deciduous forest and oak forests. In La Huacana, they are associated to thorn forest and small creeks with elements of semi-evergreen forest. The previous study carried out to justify the creation of Zicuiran-Infiernillo Biosphere Reserve mentions the importance of the tropical deciduous forest (100,000 ha) for jaguar conservation (Conanp, 2005), although jaguar presence is not confirmed. The biosphere reserve (Conanp, 2005) covers a surface of 270,000 ha in the lower basin of the Balsas River and may represent an opportunity for the conservation and/or recovery of felids in this region of the state. The Wildlife Management Units (known as UMAs) established in the Costa-Sierra region will also be relevant for the conservation and recovery of jaguars.

Popular perception and attitudes towards jaguar conservation

In the Sierra de Vallejo in Nayarit and Cabo Corrientes in Jalisco, 25% of people surveyed did not know jaguars occurred in the region. Five percent of those surveyed consider jaguars as being dangerous. Ninety percent accept conservation of jaguars and protection of its habitat, and 70% consider that the jaguar is disappearing because of humans. Out of the livestock farmers and crop farmers interviewed 85% (n = 180), accept the importance of protecting the jaguar and admit that the cause of livestock predation is the lack of natural prey; they agree to protect the species and not persecute it as long as a compensation scheme is in place. Ten percent of livestock farmers do not want the jaguar or puma to be present under any circumstance (Figure 3). Over one-fourth of livestock farmers would agree to change their activity or make better management of livestock to reduce losses caused by predators and consider that livestock farming is an activity that generates little profit.

In the Nahua community of the coast of Michoacán, 95% of people surveyed agree that jaguars and natural resources must be protected, as long as there are no impositions and their rights to the land are not limited. Seventy three percent consider the species to be uncommon (Figure 3) and to occur in the most inacces-

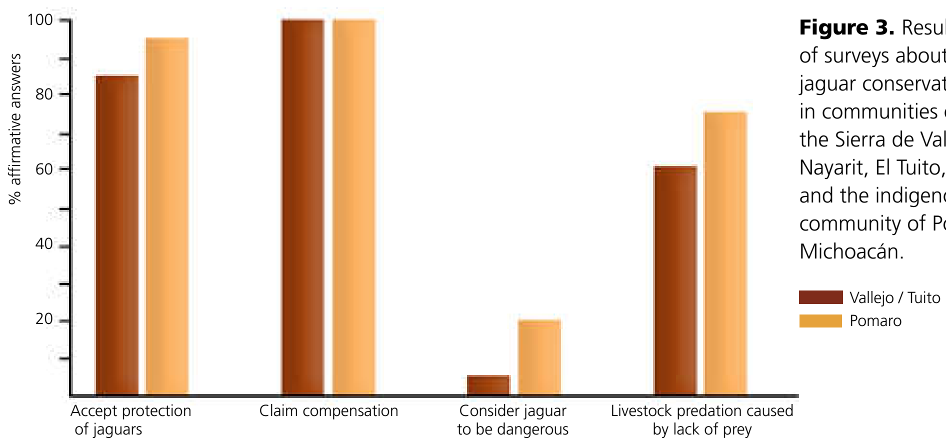


Figure 3. Results of surveys about jaguar conservation in communities of the Sierra de Vallejo, Nayarit, El Tuito, Jalisco and the indigenous community of Pomaro, Michoacán.

sible areas. In the municipalities of Lázaro Cárdenas and Arteaga, some groups are interested in conserving the jaguar through the creation of Wildlife Management Units. Regarding the decline of jaguar populations, the indigenous community of the coast of Michoacán openly admits that jaguara are uncommon because thay are killed whenever there is a chance. In northern coastal Jalisco and southern coastal Nayarit, people surveyed consider that jaguar decline is also due to the destruction of forests and the decline of its natural prey (Figure 4). In the Sierra de Vallejo, the big livestock farmers of Bahía de Banderas are against any jaguar conservation scheme, whereas smaller farmers on the Pacific side and in the mountains are more willing to protect the species.

Main issues and conservation implications

Habitat loss has been one of the main causes of the disappearance of jaguars (Núñez *et al.*, 2000). In western Mexico –particularly Jalisco– jaguar habitat started to shrink in the 1940s as a consequence of coastal settlement programs. The construction of federal coastal road No. 200 in 1970 dramatically increased the human population, the use of resources and the development of agriculture (Miranda, 1998). Jaguar habitat is currently fragmented. On the coast of Jalisco, an annual deforestation rate of 3.2% was estimated for the tropical deciduous forest, and a rate of 2.3% for the region of Marismas Nacionales (Berlanga *et al.*, 2004; Miranda, 1998). At the current rate, the tropical deciduous forest of the coast of Jalisco may have disappeared by 2050. The trend is very similar in Nayarit.

The introduction of cattle in the forest ecosystems of Jalisco and Nayarit has reduced the quality of the habitat because of the competition for food and habitat with other wild herbivores. Although livestock farming and sustainable use of forests are

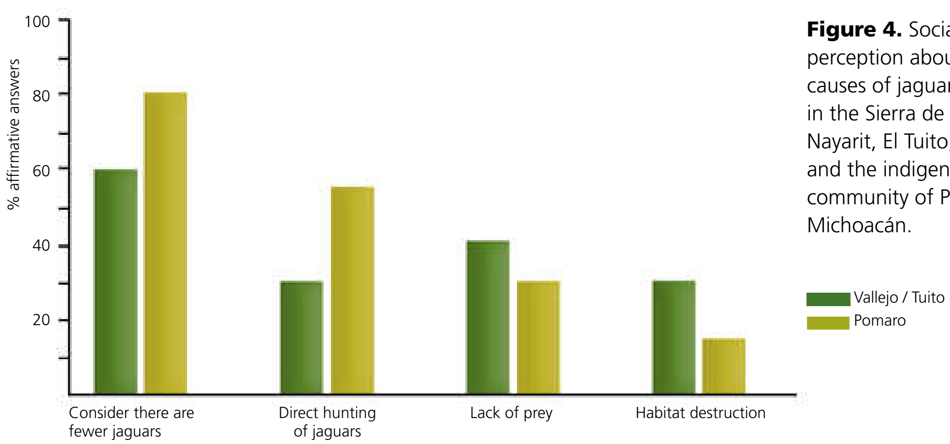


Figure 4. Social perception about causes of jaguar decline in the Sierra de Vallejo, Nayarit, El Tuito, Jalisco and the indigenous community of Pomaro, Michoacán.

not necessarily mutually exclusive, they are not integrated at present and livestock farming is displacing the forest (Curiel and Ramos, 2003).

The continuous construction of roads on the coast of Jalisco and in the mountains of Nayarit (Semarnat, 2005) is creating significant, permanent fragmentation of the habitat and natural corridors of wild animals (Ruediger, 1996). Paved roads have been proven to increase large felids mortality caused by road accidents and poaching and modify the behavior of the animals, which avoid using areas close to roads (Kerley *et al.*, 2002; Maehr, 1997; Zarza *et al.*, 2005; this volume). Roads also contribute to the establishment of new human settlements (Ruediger, 1996). The municipalities of Cabo Corrientes and Puerto Vallarta in Jalisco and Bahía de Banderas in Nayarit, which include one of the key areas for jaguar conservation, are experiencing the highest population growth in the region (Conapo, 2000; Juárez and Sánchez, 2003). Tourist developments have been planned in areas of great importance for jaguar conservation, such as the Chamela-Cuixmala Biosphere Reserve in Jalisco (Instituto de Biología, 2007), Marismas Nacionales and Sierra de Vallejo in Nayarit, among others (COPLANEDAY, 2003).

Other infrastructure works such as the hydroelectric dams built by the Federal Electricity Commission in Aguamilpa, El Cajón, and La Yesca in the near future, will have a major impact on jaguar populations. The dams will form a series of artificial lakes at different elevations with a length of more than 150 km from the center of the state of Nayarit to the boundary with Jalisco. This may limit the dispersal of felids, among other negative effects.

To reduce the impact of development on carnivores, infrastructure development must be planned in close coordination between specialists, authorities and institutions in charge of the works. It is also necessary to monitor the effect of the infrastructure on felid populations and apply mitigation measures in areas where problems are detected.

Livestock-jaguar conflict

The greatest threat for the jaguar is lethal control resulting from livestock predation and other causes. According to the reports of the active community observers in the state of Jalisco, it was estimated that 14 to 18 jaguars were killed for this reason in 2006. For example, at least two jaguars were poisoned and one was shot dead in the Sierra de Vallejo. In the municipality of Aquila, Michoacán, one jaguar was killed in 2005 because it had attacked and eaten a horse. Livestock depredation by jaguars has been attributed to different causes, from individuals unable to hunt natural prey due to consumption by humans –old individuals, inexperienced juveniles or injured animals– to the lack of natural prey or the high availability of free-grazing livestock (Hoogesteijn, 2001; Polisar *et al.*, 2003; Rabinowitz, 1986). In the study area, the lack of natural prey is probably the most important cause of livestock predation. In Sierra de Vallejo, the lack of natural prey such as the peccary (*Tayassu tajacu*) and the white-tailed deer (*Odocoileus virginianus*) and high availability of cattle aggravate the problem. In contrast, reports of livestock predation are not frequent in the Chamela-Cuixmala Biosphere Reserve, in Jalisco, where jaguars are common and natural prey are abundant (Núñez, 2006). Some areas such as Sierra de Vallejo and Cabo Corrientes are under strong hunting pressure. Camera trapping showed a low abundance of peccary and white-tailed deer compared to the relative abundance of the jaguar, 2 or 3 times higher than that of its prey; in the biosphere reserve, however, the relative abundance of deer is 3 times higher than that of jaguars.

In Jalisco, 3 areas with the greatest level of conflict with livestock farming were identified: a) Sierra de Manantlán, b) Tomatlán and c) Cabo Corrientes. In Nayarit, 3 conflict areas were identified: a) Sierra de Vallejo-Zapotan, b) Marismas-San Blás and c) the municipality of Santa María del Oro. Livestock farming is extensive and unmanaged in all these areas. The lack of natural prey and availability of livestock contribute to the attacks. The jaguar is an opportunist (Seymour, 1989) and versatile species. If natural prey is not available, it readily uses other resources, from cattle to dogs to poultry. Jaguars usually attack young or newborn livestock. According to livestock farmers and cowboys interviewed, 'in the country, when cows are about to calve, they go to a remote place in the woods and stay there with their calf for a few days.' Lack of management and surveillance of these calving females facilitates attacks.

To reduce the conflict between livestock and jaguars, the problem must be tackled on three fronts: a) livestock farmers must be given advice on how to improve management and care of their herds, b) there must be more surveillance and increased awareness among hunters, and c) alternative sources of income must be implemented to reduce overexploitation of wildlife. It is very important to assist livestock farmers promptly when they ask for help after a felid has attacked their herd; if they are ignored they will bring hunters in to solve the problem.

Long-term conservation

Due to habitat fragmentation, there is no continuous population, but rather, a number of more or less isolated small populations –some of which are of a larger size and greater importance– connected by vegetation corridors, forming a metapopulation. According to Eizirik *et al.* (2002), 650 individuals are necessary for long-term conservation of the jaguar and to maintain genetic variability in a region. To maintain a population of this size, roughly 24,000 km^2 to 38,000 km^2 and would be necessary. Calculation of the values was based on a density of 1.7 and 2.7 individuals/100 km^2, obtained by radio telemetry in the RBCC from 1996 to 1997 (Núñez *et al.*, 2000) and 2000 to 2003 (Núñez, 2006).

In western Mexico, ideally, a population of 140 individuals (3.5 individuals/100 km^2) could occupy an area of 4,500 km^2; without human threats, it would have a 90% probability of persisting for more than 100 years. When the anthropogenic effect is included in the model, the population declines to 50% in 10 to 20 years, and is practically extirpated at 40 years (Carrillo *et al.*, this volume). It is not possible to maintain one single large population in western Mexico. Yet, if connectivity between the protected areas that maintain the jaguar is ensured (Table 1), the exchange of individuals will continue (Beier, 1993). For example, the region that encompasses Tomatlán-Cabo Corrientes-Rio Ameca-Sierra de Vallejo covers about 2,700 km^2 and must be protected in its entirety as a jaguar conservation unit; this area can sustain over 50 jaguars (Allen *et al.*, 2001) and is also connected to the region of the RBCC. The creation of corridors and protection zones must be supported by other schemes providing economic and productive alternatives that reduce the pressure on wildlife.

Perspectives

In western Mexico several groups are cooperating in the ongoing search for physical records of jaguar presence. It is important to increase the effort devoted to the search for records in oak and pine forests in Nayarit, Jalisco and Michoacán, as this vegetation type might be a refuge for jaguars because it is under less pressure than other types of forests. The thorn forests of Tierra Caliente in Michoacán must also be explored to confirm the presence of the jaguar in the region and determine whether there is a population or just dispersing individuals. It is important to define and protect corridors that guarantee the exchange of individuals between populations. Radio telemetry studies are needed to determine the use of fragmented areas by jaguars and identify potential corridors. The conflict caused by livestock predation must urgently be studied and dealt with in order to achieve a greater acceptance of jaguar conservation and reduce the persecution of the species. The first studies to determine the status of the jaguar in Marismas Nacionales (Nayarit) are now under way. It is necessary to conduct a population assessment of the jaguar in this region, which may contain a considerable number of individuals.

Acknowledgments

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DETERMINING CRITICAL AREAS FOR THE SURVIVAL OF JAGUARS IN THE SIERRA MADRE ORIENTAL

O. Eric Ramírez Bravo and Carlos A. López González

Resumen

Las montañas de la Sierra Madre Oriental de México representan una de las áreas marginales de la distribución del jaguar (*Panthera onca*) pero es poco lo que se conoce de la especie en la región y de las áreas prioritarias para su conservación. Con este propósito se utilizó un modelo dinámico (PATCH) para determinar áreas prioritarias en la Sierra Madre Oriental, basados en probabilidades de mortalidad, representadas por la densidad de población humana y la densidad de carreteras, y de supervivencia, mediante un índice de vegetación y aspectos fisiográficos. Estas probabilidades fueron estimadas por medio de un modelo estático. Se consideraron 3 escenarios diferentes: condiciones actuales, crecimiento en población humana a 15 años y el incremento en la densidad de carreteras en el mismo lapso. Los resultados muestran que manteniendo las condiciones actuales del hábitat, el jaguar puede sobrevivir en un lapso de 200 años. Sin embargo, el incremento en la población humana y en la densidad de caminos ocasionaría la extinción de la especie en un lapso de 50 años debido a un aumento de conflictos. Los resultados de este modelo son útiles para dirigir recursos en las áreas prioritarias para la supervivencia de poblaciones de jaguar a largo plazo.

Abstract

*Due to habitat loss, it is necessary to identify areas with potential viability for endangered species. In the case of jaguars (*Panthera onca*) little is known for marginal distributional areas, making it necessary to create conservation strategies to assure long term survival. For this purpose, a spatial dynamic model (PATCH) was used to determine priority areas in the Sierra Madre Oriental, México. Mortality (human population density and paved road density) and survival probability (vegetation index and physiographic aspects) were estimated using a static model. Three scenarios were considered: actual conditions, human population growth in 15 years, and paved road density increase in 15 years. Results showed that current conditions provide sufficient habitat for jaguar survival in a 200 year span. However, increase in human population and road density will result in species extinction in a 50 year span due to an increase in possible conflicts. The results of this model will help to concentrate resources into certain areas to assure longterm survival for jaguar populations.*

Introduction

Jaguar conservation requires the implementation of several measures, such as the protection of large areas and the development of national and international strategic plans. Although there is a great deal of information available, most of it does not include population data (Sunquist, 2002). In Mexico, certain areas can be considered key for jaguar conservation, but there are no studies on the existence of jaguar populations or habitat quality in most of the country (Chávez and Ceballos, 2006). This is the case of Querétaro, San Luis Potosí and Hidalgo, at the northeast end of the species' range, where there are confirmed reports of jaguar presence but no information is available on its population status. Individuals in these states are relevant to the conservation of the species, given that their movements between small populations may reduce their extinction risk. In cases where information about the species is limited, the use of predictive models has been proposed to identify the probability of occurrence of a species (e.g., Jiménez, 2005). Habitat prediction aims at providing a simple and clear representation of the most important environmental factors that may influence the distribution of a species (Morrison *et al.*, 1992).

The use of such models has become increasingly important in conservation biology, since it helps understand the factors that determine the distribution of the different habitats in the landscape (Naves *et al.*, 2003). Predictive models have been used to issue recommendations for the recovery and conservation of other species of carnivores (Ferreras *et al.* 2001, Carroll *et al.* 2006). In the case of jaguars, it is necessary to analyze the suitability of habitat in northeastern Mexico as a first step so that the importance of such areas for jaguar conservation can be determined.

In spite of the efficiency of habitat prediction models, these models only show areas where the presence of the species is likely, but do not provide information about population size or trends (Morrison *et al.*, 1992). For this reason, this study used PATCH, a spatially explicit population model, which combines data on the spatial arrangement of the habitat with data on the behavior of the species in different vegetation types (Carroll *et al.*, 2006).

The development of the model was based on the study carried out by Ortega-Urrieta (2006), who found traces of jaguar presence in the area and proved the existence of habitat where the species may occur in the region. The objective of this study was to determine critical areas for the survival of the jaguar in a period of 200 years (Carroll, 2006) as a first approach to the long-term conservation of the species in the states of San Luis Potosí, Guanajuato, Querétaro and Hidalgo.

Study area

The study area was delimited on the basis of the hydrologic region known as Confluencia de las Huastecas, the mammal-based zoogeographical province of the Sierra Madre Oriental and the geographic boundaries of the states of San Luis Potosí, Hidalgo and Guanajuato. It included an area of 56,487 km^2 with favorable habitats for the species, such as cloud forest and tropical deciduous forest (Figure 1). According to the Mexican National Municipal Information System (SNIM ver. 7.0), the average human population density is 62.2 individuals/km^2, which tends to be greater in urban areas.

Methods

We used the Program to Assist in Tracking Critical Habitats, known as PATCH (Schumaker, 1998), which has previously been used to determine important areas for the conservation of other carnivores such as wolf and lynx (Carroll, 2005; Carroll *et al.*, 2006). This program combines demographic variables and information obtained through environmental variables processed in a Geographic Information System (GIS), ArcView 3.2 in this case (ESRI, 2000; Figure 2a). PATCH uses this information to create a hexagonal grid on the image so that the analyses can be made. Values obtained through the HSI (Habitat Suitability Index) are then attributed to the different habitats in the study area. The next step is to introduce maximum and minimum home range values recorded for the species and mean dispersal distance. Finally, survival and fecundity rates obtained from earlier studies are introduced in a Leslie matrix. PATCH calculates the values for the probabilities of other habitats by extrapolating the values of the table. This combines the survival probabilities of each habitat obtained through the GIS and the life history of the species, identifying sources, sinks and unsuitable areas (Figure 3).

Figure 1. Location of the study area.

Selection of variables

Earlier studies using this program (Carroll, 2005; Carroll *et al.*, 2006) recommend using 2 static variables (survival and fertility rates) to calculate the habitat suitability index (Figure 3). This was calculated using 30 presence-absence data units to determine the indices with the method used by Jiménez (2005). According to Woodroffe and Ginsberg (1998), a high proportion of deaths of large carnivores are due to anthropogenic factors or their effects on the environment. Therefore, it is possible to obtain an approximate estimate of the mortality rate by using human population density and paved roads. This is shown in other earlier models (Ferreras *et al.*, 2001; Glenz *et al.*, 2001; Naves *et al.* 1999).

Fecundity was calculated using aspect, slope, elevation and vegetation type (Ortega-Huerta and Medley, 1999). Vegetation type is based on productivity, calcu-

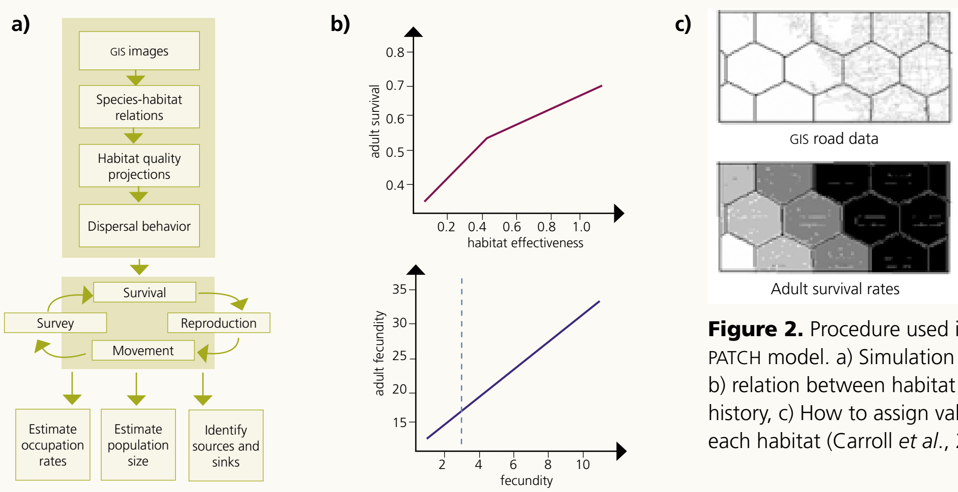

Figure 2. Procedure used in the PATCH model. a) Simulation process, b) relation between habitat and life history, c) How to assign values to each habitat (Carroll *et al.*, 2006).

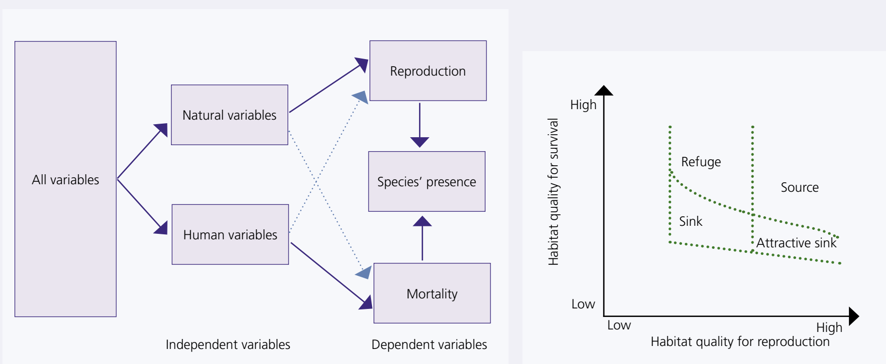

Figure 3. Identification of habitat types by overlaying survival and fecundity maps (Naves *et al.*, 2003).

lated with the NDVI (Normalized Difference Vegetation Index) obtained from satellite images. The NDVI uses spectral bands captured in images to distinguish between areas covered with vegetation and areas with no apparent vegetation (Brun, 2004).

The digital layers used for these calculations were obtained from the Mexican National Commission for the Knowledge and Use of Biodiversity (Conabio). Aspect, slope and elevation values were obtained with a digital elevation model. The NDVI was obtained from LANDSAT ETM satellite images freely available from NASA. The entire analysis was made using a 1:250 000 scale, as it was the most detailed resolution available in the data banks. We used a 10 km^2 cell as our minimum unit because it is the smallest home range reported (Crashaw and Quigley, 2002).

Population parameters

We used the population parameters considered by Eizirik *et al.* (2002) to model a population in South America. These data were obtained by reviewing several studies carried out with different species of large felids. We developed the Leslie matrix by grouping individuals according to the 6 categories shown in Table 1. The survival rate of dispersing individuals is based on the rate calculated for pumas by Beier (1993). The change in the home range was obtained by analyzing studies carried out in Chamela-Cuixmala, Jalisco (Núñez *et al.*, 2002), Calakmul, Campeche (Ceballos et al., 2002), Belize (Rabinowitz and Nottingham, 1986), the Venezuelan Plains (Hoogesteijn *et al.*, 2002) and the Pantanal, Brazil (Quigley and Crawshaw, 2002).

Analysis

We analyzed 4 different scenarios based on the following variables:

1) Current situation. 2) Situation with a positive growth in the road density of every municipality over the next 15 years (based on data from INEGI, the Mexican National Institute of Statistics and Geography). 3) Situation with a positive growth in human population density over the next 15 years, based on the records of the previous 15 years for each municipality (based on data from SNIM). 4) Situation

Table 1. Demographic variables provided to PATCH

Size of territory: 58.43 km^2
Maximum dispersal distance: 100 km
Survival rates (maximum):
- Young (0 -2 years): 0.66
- Dispersers (2 years): 0.65
- Adults (> 2 years): 0.80
- Old (> 10 years): 0.80

Fecundity rates (maximum number of female offspring/female):
- Young (0 -2 years): 0
- Dispersers (2 years): 1.36
- Adults (> 2 years): 1.19

with trends in human population density –growth and decline– for the next 15 years based on the records of the previous 15 years for each municipality (based on data from SNIM).

Each scenario was run 100 times with a 200-year timeframe, and results were analyzed from year 101 for greater reliability.

Results

The linear regression formula obtained for each of the indices was the following:

$$\text{Survival index} = \frac{1}{e^{Slope\,(0.0114)+Elev\,(-0.2320)+Aspect\,(0.0393)+\,Veg\,(0.4121)+\,1.286}+1}$$

$$\text{Mortality index} = \frac{1}{e^{Road\,(-0.1158)\,+\,Pob\,(0.0384)\,+\,0.96321}}$$

Where Elev = elevation, Veg = NDVI vegetation index, Road = road density, and Pop = population density.

The dynamic model showed that there is a great deal of favorable habitat in San Luis Potosí and Hidalgo for long-term survival of jaguars in the region, with a population of 130 females and an undetermined number of males, cubs, and dispersing individuals. Connectivity in the region allows interaction with populations in Tamaulipas, Nuevo León and Veracruz (Figure 4a).

However, the increase in road density and human population in the region considerably reduces the habitat available for jaguars. This suggests that if no measures are taken to mitigate these factors, jaguar survival time in this area will decrease to less than 50 years. The source populations in the maps correspond to areas identified as important for jaguar survival in a 50-year timeframe (Figures 4b and c).

Although the static model shows areas with suitable habitat for the species, fragmentation prevents long-term survival of populations. However, there is an area where human population is decreasing that can maintain a viable jaguar population as long as greater protection measures are taken (Figure 5). Figure 6 shows areas considered as sources, sinks and unsuitable areas.

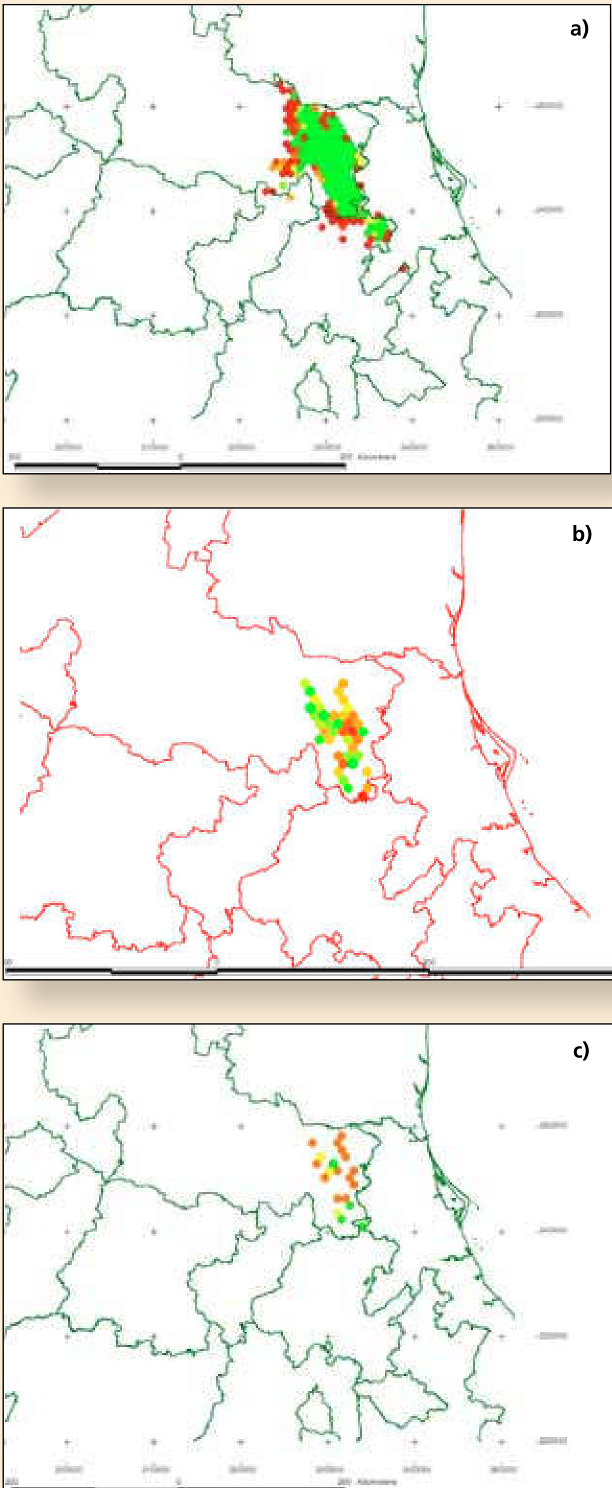

Figure 4. Areas occupied by jaguar females in a 200 year period. Green and red designate sources and sinks respectively; intermediate colors are variations in grid quality with (a) current conditions, (b) a simulated increase in road density in the next 15 years and (c) a simulated increase in human population density in the next 15 years.

Discussion

It is necessary to generate methods that contribute to an accurate assessment of carnivore habitat so that management plans can be developed at a low cost in Latin America. Data on prey density are considered to provide good estimates of reproductive rates (Naves *et al.*, 2003). Since jaguars are reported to have a broad range of prey (e.g., Garla *et al.*, 2001; Núñez *et al.*, 2002), it would be difficult to calculate reproductive rates based on prey data. However, the use of satellite images produces

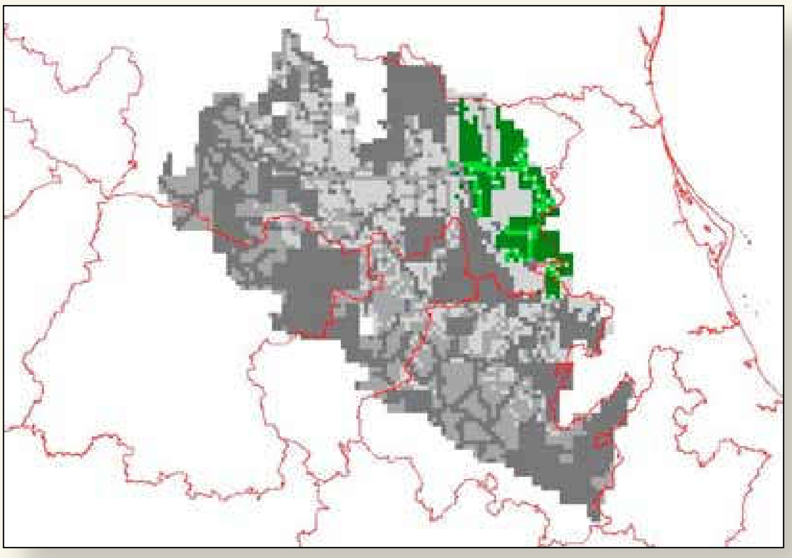

Figure 5. (a) Areas of jaguar habitat resulting from a 15-year projection of current population trends, and (b) areas occupied by jaguar females after increasing protection in areas where human population is decreasing.

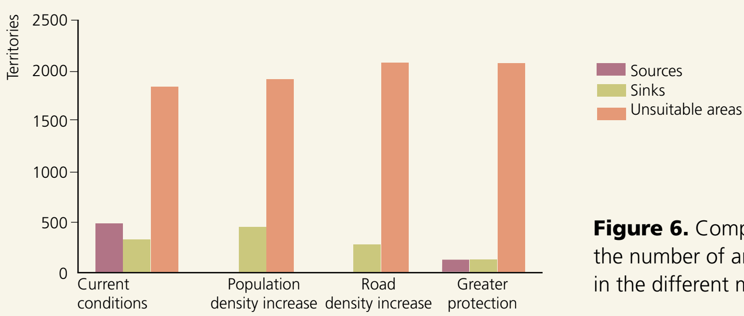

Figure 6. Comparison between the number of areas identified in the different models.

good results by linking reproductive rate to habitat productivity. Moreover, data obtained so far by Villordo-Galván and Rosas-Rosas (pers. comm.) for the area of San Luis Potosí prove the reliability of the static model.

Based on this model, it can be concluded that the area has suitable habitat for jaguars and allows its long-term survival in its current state if some minimal, urgent conservation measures are taken. However, these areas are surrounded by others that can be considered buffer zones but are subjected to a high level of anthropogenic activities. Some of these areas, such as agricultural ones, may increase the density of prey –i.e., peccaries– in the region (O. Rosas-Rosas, pers. comm.). A lack of suitable habitat or sources and a low density of jaguars were observed in Sierra Gorda Biosphere Reserve (Ortega-Urrieta, 2006). In these cases, marginal areas tend to be used by juveniles or adult individuals with very large territories, as has been observed in other species such as the Florida panther (*Puma concolor coryii*), whose territory size decreases as its quality improves, and vice versa (Maher and Deason, 2002). This information can be used to generate regional conservation and management plans. Inbreeding problems can be prevented by ensuring connectivity between populations (Eizirik *et al.*, 2001). Additionally, the model makes it possible to determine spatial relations between the different habitat patches in the area (Fahrig and Merriman, 1994).

The spatially explicit model shows the importance of the area for long-term conservation of the species. However, the results should be considered with caution, mainly because of the uncertainty about the population parameters used for jaguars. The model obtained from the current situation is the optimistic one and reflects the conditions that it is necessary to try to maintain in the region. Most areas available for jaguars according to the model are located in the mountains, which are difficult to access and limit changes in land use. The model considers some agricultural areas as long-term source populations, which may be due to the increase of prey species, but may also be the result of the uncertainty associated to long-term predictions. In the state of Guanajuato, a region with suitable habitat for the species was identified, but it is isolated and connections with other existing populations are not possible. Therefore, if jaguars are present in the area, their populations are not viable in the long term.

The model based on an increase in road density and human population density over the next 15 years predicts the extinction of the populations in the study area in a period of 50 years. The increased fragmentation of the habitat caused by both factors may lead to changes in the behavior of individuals, as happened with the Florida panther (Maher and Deason, 2002). This may cause the loss of isolated populations and high mortality in some of the patches considered viable. In principle, a negative change in habitat productivity leads to larger home ranges, increases intraspecific competition (Maehr *et al.*, 1992) and causes it to start at an earlier age (Lidicker, 1962). In pumas, movements of dispersing individuals have been recorded to be smaller and circular in areas where anthropogenic factors limit colonization of new habitats (Maehr *et al.*, 2002). This leads to an increase of deaths caused by road accidents because the factors of the landscape contribute to the use of roads by the animals (Maher *et al.*, 1991). Frustrated dispersal also occurs when insufficient vacant range exists to accommodate dispersers, or when suitable vacant range does not contain individuals of the opposite sex (Maehr *et al.*, 2002).

If the population becomes isolated because of human population growth or road density, a management program promoting supplementation with new individuals will be necessary (Maehr *et al.*, 2002). Although some authors have suggested the selective capture of old or problem individuals a possible management option in the area (O. Rosas-Rosas, pers. comm.), the occasional hunting of large felids has been proven to be unsustainable (Lindzey *et al.*, 1992; Kenney, 1995). In view of the above, the best conservation program would imply maintaining connectivity among the populations that exist in the region.

Perspectives

This is the first study conducted in the region. It shows that the area is important for northern jaguar populations. The use of PATCH is new in Mexico, as this is the first study that combines habitat aspects with demographic variables. This makes it possible to identify important areas for the management and conservation of the species in this area, which contains enough habitat to maintain a viable jaguar population in the long term. It is therefore urgent and necessary to develop a management plan for the region that includes the creation of protected areas of various categories and work with communities to reduce jaguar deaths. We recommend using this approach for other areas where data are scarce, as it helps complete gaps in the information needed to define management measures at the ecosystem level.

Acknowledgments

We wish to thank all the people who cooperated in this project, as it would not have been possible without them. We owe a debt of gratitude to the reviewers who helped us give shape to the manuscript and make it understandable. We are also grateful for the support provided by Conacyt (Semarnat-2002-C01-0388); Instituto de Ecología A.C., Naturalia, Denver Zoo, Wildlife Conservation Society (WCS) and Cuenca Los Ojos, for providing the funding for the project.

JAGUARS IN THE EAST OF THE HUASTECA REGION IN SAN LUIS POTOSÍ

Lissette Leyequién and Rosa María Balvanera

Resumen

La única Reserva de la Biosfera de San Luis Potosí es la Sierra del Abra Tanchipa, por lo que su cuidado y manejo constituyen una de las prioridades dentro del estado. Con el fin de proponer un plan de manejo en esta reserva, se realizó una revisión bibliográfica de la flora y fauna del área, así como un listado de la fauna silvestre. El estudio está enfocado a las presas potenciales del jaguar, este trabajo generó las primeras propuestas para la conservación del hábitat. El área de estudio se dividió en norte, sur y centro; se analizó la distribución espacial y la frecuencia de las especies por medio de entrevistas a los pobladores locales y registros en transectos. Se realizaron recorridos y se registró la presencia de las especies mediante huellas y excretas. Además, se registraron los tipos de vegetación presentes en el área. Se registró venado cola blanca (*Odocoileus virginianus*), venado temazate (*Mazama temama*), pecarí de collar (*Tayassu tajacu*), hocofaisán (*Crax rubra*) y armadillo (*Dasypus novemcinctus*) como presas potenciales del jaguar. La zona sur del área de estudio mostró un elevado grado de perturbación y está sujeta a una mayor presión por su cercanía a los poblados, por lo que se obtuvieron menos registros, especialmente de los mamíferos mayores.

Plabras clave: Huasteca Potosina, San Luis Potosí, Sierra del Abra Tanchipa, jaguar.

Abstract

*The Biosphere Reserve Sierra of the Abra Tanchipa is the only Biosphere Reserve inside San Luis Potosí, as such, its adequate management constitutes one of the priorities within this state. As the basis for a management plan, we conducted a bibliographic review of the fauna and flora of the area, as well as a preliminary inventory of the wild fauna in the area. Special attention was given to the presence and status of the potential prey of jaguars. This work provided the first guidelines to prepare a first proposal of habitat management and conservation. This involves dealing with critical environmental elements, mainly regarding the cultural and economic vision of the human communities that coexist with jaguars. The study area was divided in three zones; north, south and central. The spatial distribution and frequency of the species was analyzed from data obtained from local residents by means of interviews, and transects to search for tracks and faeces. The different vegetation types were also recorded. Jaguars's potential prey species recorded included white-tailed deer (*Odocoileus virginianus*), brocket deer (*Mazama temama*), white-collared peccary (*Tayassu tajacu*), great curassow (*Crax rubra*) and armadillo (*Dasypus novemcinctus*). The southern area is more disturbed and has greater*

pressure from the villages than the rest, consequently, there were fewer records from this area, particularly for large mammals. This means that the southern area is under greater human pressure given its vicinity to many human settlements.

Key words: Huasteca Potosina, San Luis Potosí, Sierra of the Abra Tanchipa, jaguar.

Introduction

This is a preliminary analysis of the status of jaguars in the east of the Huasteca region, in the state of San Luis Potosí. This area includes the municipalities of Valles (Sierra del Abra Tanchipa), Xilitla, Tampamolón de Corona, San Antonio, Tancanhuitz de Santos, Aquismón and Huehuetlán (Figure 1). This study was carried out in full compliance with all relevant legislation in Mexico. To design the strategy, the following activities were considered important:

- Reviewing and compiling documents and local reports, studies and research on jaguars.
- Detecting and analyzing presence/absence of jaguars and species reported as its prey.
- Examining the spatial distribution and frequency of occurrence of jaguars and its prey through an analysis of the vegetation in the area and in-situ observation and transect walks.
- Analyzing the current status of plant and animal communities to obtain greater information about the degree of conservation and disturbance of the area.

Figure 1. Jaguar study area in eastern San Luis Potosí.

These activities provide information to develop a first proposal for habitat conservation, including the management of environmental, cultural and economic elements and involving human communities that coexist with jaguars.

Objectives

- Prepare a proposal for the conservation of jaguar habitat that takes into account the area's current degree of fragmentation.
- Promote habitat restoration programs to connect the different patches of forest and form a corridor.
- Raise awareness in local society about the importance of conserving jaguars.
- Contribute to provide sources of income based on sustainable use of resources to people in communities that coexist with jaguars.

Methods

We carried out a bibliographic review of studies and reports from 1987 to date about issues related to the study area and the target species. The presence/absence of jaguars was determined through a compilation of bibliographic material, surveys about the presence of jaguars and its potential prey and *in situ* transect walks.

The spatial distribution and frequency of occurrence of the species were analyzed by means of interviews with local people and transect walks to record the presence of the species (direct observation, tracks and scats). The formulas were determined sensu Clemente (1996) as follows:

Frequency = number of times an event happens in one site

Prevalence = frequency / number of sites

The biodiversity of the area was analyzed in cooperation with Fundación Edward Seler. The Simpson (λ) and Shannon Weaver (H') indices and evenness (E5) or modified Hill's ratio were calculated according to the formulas of the Ecolab statistical package (Ludwig and Reynolds, 1988). Separate and combined calculations were made for mammals, birds and reptiles for the whole area and the areas where the transects were located.

The conservation status of the species was determined following the Mexican legislation (NOM-059-Semarnat-2001), CITES and the IUCN Red List. The use of the species was classified into hunting, scientific, medicinal, personal consumption, crafts (used to make crafts) and ornamental. The various vegetation types in the area were recorded by determining their main characteristics with the standard hectare method (Franco *et al.*, 1985). We identified the main plant species present and estimated density, basal area and crown cover and volume according to Matteucci and Matteucci and Colma (1982) and Gómez-Pompa (1988). To analyze the data, the reserve was divided into three zones –north, south and central– according to its vegetation.

Results and discussion

The bibliographic review showed the existence of only five studies, including the designation of the reserve as a protected area and its management proposal, that mention the presence of jaguars in the area.

Sierra del Abra Tanchipa Biosphere Reserve mantains to five species of felids – jaguar (*Panthera onca*), margay (*Leopardus wiedii*), ocelot (*Leopardus pardalis*), jaguarundi (*Puma yaguaroundi*) and puma (*Puma concolor*). All these species, except for the jaguarundi, are considered threatened, and puma which is not included in the list, are endangered according to the Mexican Endangered Species List (NOM-059-Semarnat-2001) and listed in CITES Appendix I. Jaguars and margay are included in the IUCN Red List as Near Threatened, while the other three species are included in the same list as Least Concern. We also identified 24 species of birds listed in the Mexican Endangered Species List (NOM-059-Semarnat-2001), such as the mottled owl (*Ciccaba virgata*), great curassow (*Crax rubra*), red-crowned Amazon (*Amazona viridigenalis*), and military macaw (*Ara militaris*). The latter two are also listed in CITES Appendix I and also are included in the IUCN Red List as Endangered (Table 1).

The following species have been reported as jaguar prey in other studies: white-tailed deer (*Odocoileus virginianus*), brocket deer (*Mazama temama*), collared peccary (*Tayassu tajacu*), great curassow (*Crax rubra*), armadillo (*Dasypus novemcinctus*), rabbit (*Sylvilagus floridanus*), jackrabbit (*Lepus californicus*), white-nosed coati (*Nasua narica*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), opossum (*Didelphis marsupialis*) and crested guan (*Penelope purpurascens*) (Amín, 2004; Chávez, *et al.*, in this volume; Oliveira, 2002). Local people use at least 20 species of mammals for hunting, medicinal, ritual or subsistence purposes, most importantly jaguars, ocelot and white-tailed deer. They use at least 30 species of birds for different purposes, including the bobwhite quail (*Colinus virginianus*), wild turkey (*Meleagris gallopavo*), green parakeet (*Aratinga holochlora*), red-crowned Amazon and military macaw. These birds are under great pressure from hunting and illegal trade. Local people usually kill any snakes they come across, besides using them –particularly species of the genus *Crotalus*– for medicinal and ritual purposes (Seler, 2000).

The floristic study provides an overview of the communities and their vegetation types, the most important of which are tropical deciduous forest, semi-evergreen forest and secondary vegetation known as acahual (Puig, 1991). Thorn scrub is present in some areas, depending on the degree of disturbance of the vegetation. Reported species associations include, zoyate and a species of palm. Vegetation density was very similar in the three zones (Friedman ANOVA by ranks; $p = 0.703$), as well as the estimation of crown cover (Friedman ANOVA by ranks; $p = 0.117$). However, crown volume varied significantly between the three zones (Friedman ANOVA by ranks; $p < 0.005$); the south zone was the most different one, whereas the north and central zones were similar to each other.

Table 1. Species of vertebrates listed in categories of threat in Sierra del Abra Tanchipa, San Luis Potosí

Common name	Scientific name	Category in Mexico	Category in CITES	IUCN Red List
Jaguar	*Panthera onca*	P	Appendix I	NT
Margay	*Leopardus wiedii*	P	Appendix I	NT
Ocelote	*Leopardus pardalis*	P	Appendix I	LC
Jaguarundi	*Puma yaguaroundi*	A	Appendix I	LC
Puma	*Puma concolor*		Appendix II	LC
Brazilian free-tailed bat	*Tadarida brasiliensis*			LC
Muscovy duck	*Cairina moschata*	P		LC
Lesser scaup	*Aythya affinis*			LC
Sharp-spinned hawk	*Accipiter striatus*	Pr	Appendix II	LC
White-tailed hawk	*Buteo albicaudatus*	Pr	Appendix II	LC
Bobwhite quail	*Colinus virginianus*	P	Appendix I	NT
Great blue heron	*Ardea herodias*	Pr		LC
Mottled owl	*Ciccaba virgata*	A	Appendix II	LC
Red-lored amazon	*Amazona autumnalis*	Pr	Appendix II	LC
Red-crowned amazon	*Amazona viridigenalis*	P	Appendix I	EN
Green parakeet	*Aratinga holochlora*	A	Appendix II	LC
Blue-crowned motmot	*Momotus momota*			LC
Pale-billed woodpecker	*Campephilus guatemalensis*	Pr		LC
Lineated woodpecker	*Dryocopus lineatus*			LC
Northern mockingbird	*Mimus polyglottos*			LC
Louisiana waterthrush	*Seiurus motacilla*			LC
Hooded oriole	*Icterus cucullatus*			LC
Altamira oriole	*Icterus gularis*			LC
White-breasted wood wren	*Hernicorhina leucosticte*			LC
Eastern towhee	*Pipilo erythrophthalmus*	Pr		LC
Canada goose	*Branta canadensis*			LC
Military macaw	*Ara militaris*	P	Appendix I	VU
Great curassow	*Crax rubra*	A		VU
Crested guan	*Penelope purpurascens*	A		LC
Yellow-crowned amazon	*Amazona ochrocephala*		Appendix II	LC
Eastern box turtle	*Terrapene carolina*	Pr	Appendix II	NT
Blue spiny lizard	*Sceloporus serrifer*	Pr		LC
Lagartija espinosa	*Sceloporus grammicus*	Pr		LC
Mesquite lizard	*Coluber constrictor*	A		LC
Racer snake	*Hypsiglena torquata*	Pr		LC
Boa	*Boa constrictor*	A	Appendix II	
Neotropical rattlesnake	*Crotalus durissus*	Pr		
Black-tailed rattlesnake	*Crotalus molossus*	Pr		LC
Cantil	*Agkistrodon bilineatus*	Pr		NT
Brown's coral snake	*Micrurus browni*	Pr		LC
Middle American Burrowing snake	*Adelphicos quadrivirgatus*	Pr		
Scorpion mud turtle	*Kinosternon scorpioides*	Pr		
Eastern coral snake	*Micrurus fulvius*	Pr		
Black-spotted newt	*Notophthalmus meridionalis*	P		EN
Rio Grande leopard frog	*Rana berlandieri*	Pr		LC

P: endangered; A: threatened; R: rare; Pr: subject to special protection.

Floristic diversity (H'= 3.78; l= 0.03) and evenness (E= 0.68) were high in the reserve. Species evenness was quite homogeneous in the three zones, although the north zone was more dominant (E = 0.42). However, diversity was found to be lower in mammals (H'= 2.25; l = 0.17) and reptiles (H'= 2.2; l = 0.12) than birds (H'= 3.3; l = 0.047). A greater dominance between species was found in mammals (E = 0.59) than birds (E = 0.74) or reptiles (E = 0.88). Differences were also found between the animals of the three zones (Friedman ANOVA by ranks p= 2.73 e-005). Again, the south zone was different form the other two (Newman-Keuls test $p < 0.05$). Frequency of occurrence of species was higher in the north and central zones (X = 38 and 37 respectively) than the south zone (X = 15.5).

These data suggest that the south zone has a greater level of disturbance. Consequently, there were fewer records of animals, particularly large mammals. Although vegetation cover in the south zone is slightly denser than in the other two areas, is under greater pressure because of the proximity of villages.

According to the indices obtained in the area, the reserve is an important area given its surface which allows sufficiently large populations to maintain genetic variability of populations of many species. The fact that several species recorded in the area are listed under some category of threat at a national or global scale makes the area highly valuable as critical habitat. According to this study, the most important environmental elements affecting the study area are the strong pressure of neighboring communities to use it and the low availability of natural watercourses, which drives animals to water bodies near human settlements –dams, for example– to satisfy their needs.

Table 2 shows jaguar records in Sierra del Abra Tanchipa Biosphere Reserve resulting from interviews and transect walks from October 2000 to February 2007. Jaguar sightings were recorded between 5 and 2 years prior to the study in the corridor between Tampamolón de Corona, San Antonio and Tancanhuitz, where the vegetation is tropical rainforest.

Conclusions

Habitat fragmentation caused by fast changes in land use affects jaguar survival. The Huasteca region of San Luis Potosí is an example of this. In less than a decade, the region has lost more than 10,000 ha of its forests, which have been transformed into sugar cane and corn plantations.

In the study area, jaguars were found to approach human settlements to satisfy their needs for water and prey. Records were obtained in the dry season, usually near dams or livestock watering ponds. Accounts of jaguar attacks on livestock also corresponded to the dry season.

Poaching is high in the area. Most hunters are reportedly from Tamaulipas, which matches the observations made in the municipality of El Naranjo, San Luis Potosí, although there are no specific records of jaguar hunting. The fact that white-tailed deer, armadillo and collared peccary are prey to both humans and jaguars generates competition for food, which has been documented in other regions (Amín, 2004; Chávez *et al.*, this volume; Escamilla *et al.*, 2000).

Perspectives

In areas with visual records of jaguar presence, there is a project to place drinking troughs in the high part of the Sierra to prevent jaguars and their prey from approaching the watering ponds and dams near villages and thus minimize human-jaguar interaction. There are plans to estimate jaguar population density in the future.

Table 2. Jaguar records including dates and type of record in Sierra del Abra, San Luis Potosí between 2000 and 2007.

Site	Date of record	Type of record	Observations
El Guajolote dam	Every year during dry season	Visual	Jaguars go to the dam to drink
Buenavista	Every year	Tracks	
El Rodeo ranch	In August three consecutive years	Visual	
El Choy	Every year in a drought	Visual and tracks	Jaguars go to the livestock watering ponds to drink
Centella dam	Five years ago	Visual	It was seen crossing the road
Limit of Cerro Alto	Every year	Visual, tracks and half-eaten prey	Resting places were found in a basement often visited by jaguars
In El Jabalí, Tres Palmas and La Palangana	Every year during dry season	Visual and tracks	Jaguars get very close to areas with livestock but no attacks have been reported
La Lajilla	Two months ago	Tracks and roars	
Pozo Salado	Two years ago	Visual	The owner of the property complains about poaching on his land
Los Patos	Three years ago	Visual and tracks	Jaguars approached the area to drink and killed a calf
San Diego	Every year, including a sighting four months ago	Visual	Two calves, a donkey and dogs were attacked

In the final stage of the study, a program was set up to restore the tropical rainforest with the cooperation and involvement of communities, especially from the municipality of Tampamolón de Corona. The aim was to concentrate efforts in restoring areas that link the remaining patches of healthy forest, to create a biological corridor that contributes to the conservation of jaguars and the other resident animal species. This initiative was launched thanks to the willingness of the inhabitants of the different ejidos, communities and local authorities to participate in jaguar habitat conservation programs. An awareness-raising and information scheme is currently being implemented in Sierra del Abra Tanchipa Biosphere Reserve, with a very good response in places where jaguar sightings have been recorded (Figure 2).

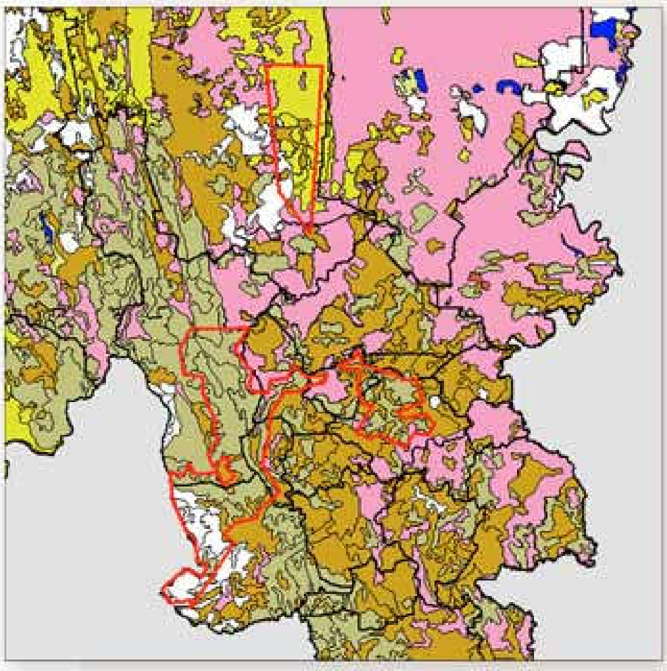

Figura 2. Current state of ecosystems in the Corridor.

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DISTRIBUTION, HABITAT USE AND ACTIVITY PATTERNS OF PUMAS AND JAGUARS IN THE STATE OF MEXICO

Octavio Monroy-Vilchis, Clarita Rodríguez-Soto,
Martha Zarco-González, and Vicente Urios

Resumen

Se analizó la distribución, uso de hábitat y patrón de actividad del jaguar (*Panthera onca*) y el puma (*Puma concolor*) en el Estado de México, por medio de registros bibliográficos, entrevistas, rastros y trampas cámara. De agosto de 2002 a mayo de 2006, se aplicaron 140 entrevistas en comunidades de la Sierra Nanchititla, se encontraron 236 rastros entre huellas y excrementos, y se obtuvieron 89 fotografías. Los felinos utilizan los bosques de pino-encino, en altitudes mayores a 1,800 msnm. La distancia a los caminos está entre los 3,509 y 4,377 m, a los poblados entre 2,326 y 4,650 m, y a pendientes pronunciadas entre 1,048 y 2,095 m para jaguar y menores a 1,047 m para puma. El periodo principal de actividad del jaguar va de 0:00 a 6:00 horas, mientras que para el puma es más amplio, pero evitando los periodos de actividad del jaguar.

Abstract

In the present study we to analyze the distribution, habitat use and activity patterns the jaguar and puma, in the State of Mexico, using bibliographic reports, interviews, signs and camera trapping. From August 2002 to May 2006, we applied 140 interviews in communities within Sierra Nanchititla, we found 236 signs, scats and footprints, and obtained 89 pictures. Both felids preferred pine-oak forest, at a higher altitude than 1,800 m. Distance to roads was between 3,509 and 4,377 m, distance to towns between 2,326 and 4,650 m, distance to rugged slopes for jaguar was between 1,048 and 2,095 m and for puma less than 1,047 m. The main activity period for jaguar was from 0:00 to 6:00, while the puma activity was broader, but avoided the period of jaguar activity.

Introduction

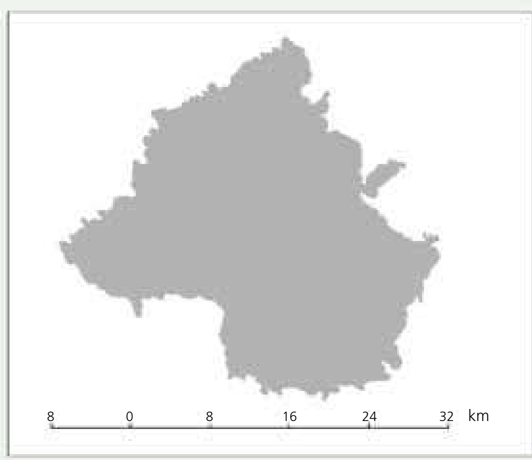
The 6 species of felids that occur in Mexico represent 50% of the species that occur on the American continent (Sunquist and Sunquist, 2002). They include the puma (*Puma concolor*), jaguarundi (*Puma yagouaroundi*), margay (*Leopardus wiedii*), ocelot (*Leopardus pardalis*), jaguar (*Panthera onca*), and bobcat (*Lynx rufus*). The State of Mexico is one of the Mexico states where all six species occur (Chávez and Ceballos, 1998). Pumas and jaguars are sympatric in the south of the state.

Few studies on these cats have been carried out in The State of Mexico. Some include lists of species (Chávez and Ceballos, 1998) and reports on distribution and new records in the state (Monroy-Vilchis *et al.*, 2005; Sánchez *et al.*, 2002). Yet, there is little information available on the ecology of these species in this region of Mexico. Ecological studies of felids are important because these species are considered to be indicators of ecosystem health, umbrella species and keystone species that maintain ecological balance, or because they provide important data for conservation status assessments and territorial planning strategies (Miller *et al.*, 1999; Sánchez *et al.*, 2002). Camera trapping is currently one of the preferred methods to study medium-sized and large carnivores. This technique uses photographic cameras that are remotely activated or triggered by a heat or motion sensor. It is highly efficient in inventories or population surveys –especially with cryptic animals whose individuals can be distinguished by their markings– and provides information on activity patterns and habitat use (Lizcano and Cavelier, 2000; Maffei *et al.*, 2002; Moruzzi *et al.*, 2002; Pinto de Sá Alves and Andriolo, 2005; Rumiz *et al.*, 2002; Trolle, 2003). In felid species, this technique has been used to assess diversity and activity patterns (Azlan and Sharma, 2006). Camera trapping is a valuable tool that can help establish conservation priorities and management programs (Silveira *et al.*, 2003). The aim of this study was to assess the distribution, habitat use and activity patterns of pumas and jaguars in State of Mexico.

Study area

The State of Mexico has a surface of 21,461 km² and is one of the states with the highest mammal diversity, which results from its great habitat diversity (Ramírez-

Figure 1. Study area, Sierra de Nanchititla in The State of Mexico.



Pulido and Castro Campillo, 1992; 1993). The state includes the two most varied physiographic and geological regions in Mexico –the Volcanic Belt and the Sierra Madre del Sur. Their rugged topographic relief contributes to the diversity of climates in the state, including warm, temperate, cold, sub-humid and dry climate. Vegetation ranges from coniferous forests to succulent scrub and tropical deciduous forest (García, 1981; INEGI, 1987).

Methods

Records of puma and jaguar presence were obtained from August 2002 to May 2006 in State of Mexico by compiling information from publications and field visits. Field visits took place in the south east of the state, in the municipalities of Luvianos and Tejupilco, which is where the species have been reported according to the literature and earlier records. Fieldwork involved conducting surveys, looking for signs and placing camera traps on trails. We used the bibliographic records in The State of Mexico that included accurate geographical coordinates. We surveyed local residents in the area, mainly to determine the presence of the species and observation sites and to find out if they had any jaguar or puma skins. The only signs considered were tracks and scats, identified according to the criteria proposed by Aranda (2000). This implied walking trails in the area every month. We placed 22 camera traps on the side of a number of trails, distributing them proportionately to the type of vegetation available. We used Wildlife Pro II Camera System traps. Each one was composed of an automatic Yashica 35 mm camera housed in a waterproof plastic, with 135 mm 36 exposure color negative film. The cameras were programmed to be operational 24 hours a day and wait 20 seconds after taking a picture. The date and time were recorded in each picture. The camera traps were inspected once a month to make sure they worked and change the film or the batteries if necessary.

In the analysis, we only used one photograph for each individual photographed by one camera at a time, and recorded the date, time and number of individuals. For each species, we excluded photographs classified as dependent events, that is, those of the same individual taken on the same occasion. This was determined by observing the sequence of movements shown by the pictures and the time recorded; in these cases the whole sequence was considered as just one record. We counted the total number of independent photographs of each species, the days when the species was photographed, the minimum and maximum number of individuals shown in one picture, photographs taken during the day and photographs taken at night. Geographical location and elevation were recorded in each case.

We calculated two relative abundance indices (RAI) according to O'Brien *et al.* (2003). RAI1 was obtained by calculating the number of trap days needed to obtain the first photograph of the target species. RAI2 was the result of dividing the number of photographs of the target species by every 100 trap days. The unit of measure of the sampling effort was trap days –considering one day as 24 hours. The total number of trap days was the sum of the trap days of each camera, that is, the number of days each of them was operational. To determine the activity patterns of both species, we calculated the percentage of independent photographs obtained in two-hour intervals.

The vegetation map was obtained from the National Forest Inventory at 1:250,000 scale (Semarnat *et al.*, 2001). To generate elevation and slope maps and determine the distance to roads and human settlements, we used 1:50,000 topographic maps (INEGI, 2003 a, b). The different types of habitat for each variable were classified with the help of ArcView 3.2 (ESRI, 1999) and IDRISI (Clarck Labs, 2003). Each vegetation type was identified as a habitat category. The types of vegetation considered were oak forest, pine-oak forest, tropical deciduous forest, secondary grassland and cropland.

For the other variables, we considered the same number of categories (6) to facilitate data handling. According to the elevation intervals registered for the types of vegetation present in Sierra de Nanchititla, the elevation variable was classified into 6 categories: the first three categories correspond to tropical deciduous forest, the fourth one corresponds to oak forest and the last two categories correspond to pine-oak forest (Rzedowski, 1994). Distances to human settlements, roads and steep slopes were classified considering the greatest potential distance for each variable. Categories of distance to human settlements in meters were 0-2325, 2326-4650, 4651-6975, 6 976-9300, 9301-11,625 and 11625-13,950. Categories of distance to roads in meters were 0-1169, 1170-2338, 2339-3508, 3509-4677, and 4678-5846 and 58487-7016. Finally, we considered slope angles of 60° or more to be steep.

Categories of distance to steep slopes in meters were 0-1047, 1048-2095, 2096-3143, 3144-4191, de 4192-5239 and 5240-6287. Slopes with a 60º angle were identified in Terrain Ruggedness Index (TRI) as being moderately steep (Hatten *et al.*, 2005). All the records were assigned to one of the categories of each variable assessed, which includes type of vegetation (pine-oak forest, oak forest, tropical deciduous forest, secondary grassland or crops), elevation interval, distance to human settlements, distance to busiest roads and distance to steepest slopes.

Table 1. Puma and jaguar records obtained in the study area

Type of record		Puma	Jaguar	Total
Surveys	Live	83	1	84
	Dead	32	2	34
Tracks	Skins	9	-	9
	Tracks	48	5	53
	Scats	163	11	174
Photographs		71	18	89
Publications		10	1	11
Total		**416**	**38**	**454**

We obtained Habitat Use Index (HUI) values with the different variables analyzed. To do so, we recorded the observed frequency of each felid in each habitat category and the corresponding frequencies expected depending on the proportion of habitat available. The HUI is obtained by subtracting the expected frequency from the observed frequency. HUI values are added, and their variability is assessed using an X^2 test (Sokal and Rohlf, 1981; Monroy-Vilchis and Velásquez, 2002).

Results and discussion

We obtained 10 bibliographic records of puma, 6 of which were less than 5 years old and came from the municipalities of Tejupilco and Luvianos, in the south of the state (Sánchez *et al.*, 2002). We only obtained one jaguar record, in the municipality of Luvianos (Monroy-Vilchis *et al.*, 2005). This region is the only one where these species are present in the state. These records were decisive in the choice of field sampling sites because they were recent.

We obtained 454 puma and jaguar records (Table 1), most of which were puma records. The surveys produced 118 puma and jaguar records (Table 2). We obtained 4 types of records through the surveys, the most frequent of which was "sightings," which amounted to 55.9% (Table 1). Sixy five percent of people surveyed were men, and 89.2% of people surveyed were over 30 years old. Eighty eight percent of the records were less than 5 years old; we used these recent records for the habitat use analysis. People surveyed were mostly crop farmers (36.4%), housekeepers (31.4%) and livestock farmers (13.4%).

We recorded 236 signs of puma and jaguar; 9 were skins (3.8%), 53 were tracks (22.4%) and 174 were scats (73.7%) (Table 1). It was not possible to identify 18 scats to the species level, so they were not included in the analysis. Besides these records, there was one sighting of a puma. We obtained 89 photographs of both species.

We obtained 37 jaguar records, most of which were tracks and photographs (92%); they all came from an area covering about 150 km². Two of the records obtained from questionnaires were 15 and 20 years old, and thus were not included in the habitat use analysis. Scats and a photograph were obtained in 2004.

Table 2. Number of records obtained from surveys and percentages of puma and jaguar

Condition	Puma Records	Puma %	Jaguar Records	Jaguar %	Total Records	Total %
Visual	64	55.6	1	33.3	65	55.0
Hunted	32	27.8	2	66.6	34	28.8
Livestock attacked	18	15.6	-	-	18	15.2
Person attacked	1	0.8	-	-	1	0.8
Total	**115**	**100**	**3**	**100**	**118**	**100**

Habitat use

According to the type of vegetation, pumas and jaguars occur most frequently in oak and pine-oak forests (Figure 2). They have been recorded at elevations greater than 1,500 m, relatively far from roads (between 2,338 and 4,677 m) and human settlements (between 2,326 and 4,650 m). Finally, both species were found in places near steep slopes (distance of less than 2,095 m).

Jaguar records show a preference for one habitat type among those assessed: pine-oak forests ($G = 62.4$; g.l. = 4, $p < 0.05$) with elevations greater than 1,800 masl ($G = 100.67$; g.l. = 5; $p < 0.05$), a distance to roads between 3,509 and 4,677 m ($G = 62.39$; g.l. = 5; $p < 0.05$), a distance to human settlements between 2,326 and 4,650 m ($G = 15.1$; g.l.v = 5; $p < 0.05$) and a distance to steep slopes between 1,048 and 2,095 m ($G = 15.102$, g.l. = 5, $p < 0.05$) (Figure 3). Jaguars probably use this habitat because it is less disturbed and therefore safer, which matches the findings obtained in other areas (Navarro-Serment *et al.*, 2005; Sunquist and Sunquist, 2002).

Although jaguar records were more common at elevations lower than 1,200 masl, the species has been recorded at 2,700 masl in Bolivia and 3,800 masl in Costa Rica (Hatten *et al.*, 2005). Studies on jaguar distribution consider the species to occur typically in warm humid or warm dry environments (López-González and Brown, 2002). However, we consider that the species is increasingly likely to be recorded in temperate areas such as Sierra de Nanchititla, because they contain less disturbed environments than the tropical ones near the coast. This has not been described as typical jaguar habitat, as it only covers about 4% of the total range of the species (Sanderson *et al.*, 2002a). This shows the lack of information available about the

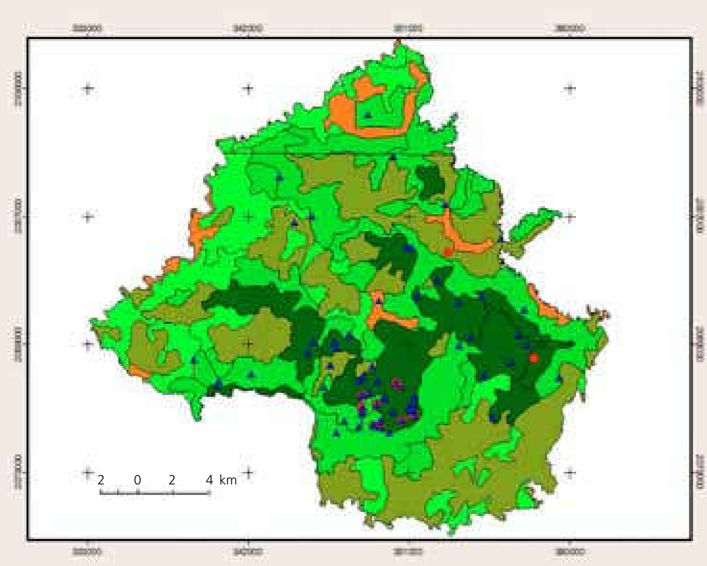
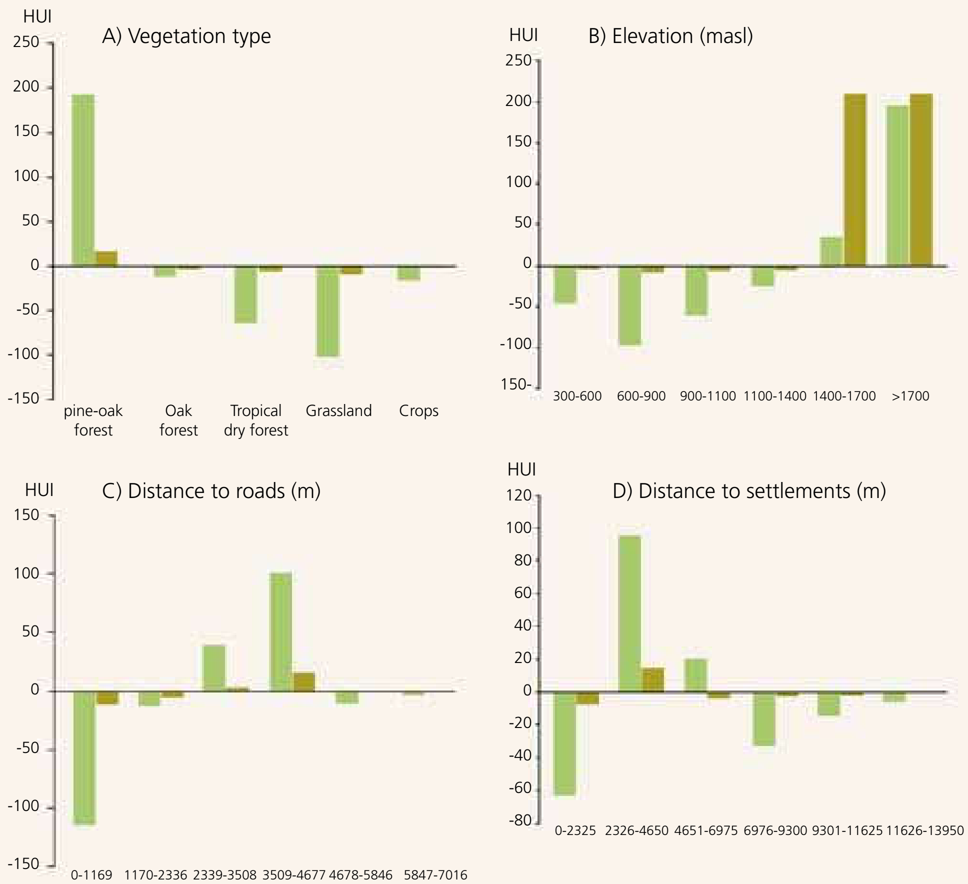


Figure 2. Map of the distribution of puma and jaguar records in different vegetation types.



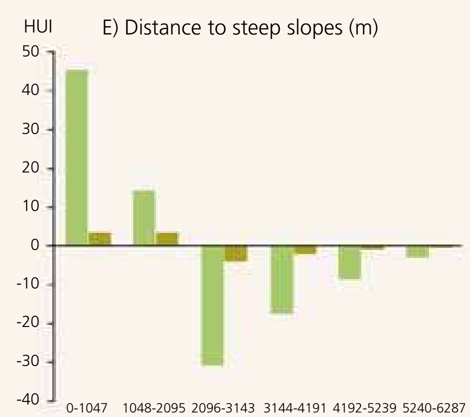


Figure 3. Habitat use index (HUI) for puma and jaguar for each variable assessed. The horizontal axis shows the habitat categories for each species in meters; the vertical axis shows the index.

jaguar in environments that may be key to its survival, by acting as natural corridors between viable populations or as reservoirs of these populations. A study about the geographic priorities for jaguar conservation in its range concluded that a jaguar survey was needed in a number of priority areas where information was not available; 30% of these areas are covered by pine-oak forest (Sanderson *et al.*, 2002b).

In all the variables assessed, puma records showed a greater use of pine-oak forests than expected ($G = 636.7$; g.l. = 4; $p < 0.05$), at elevations greater than 1,800 masl ($G = 902.3$; g.l. = 5; $p < 0.05$), a distance to roads between 3,509 and 4,677 m ($G = 329.97$; g.l. = 5; $p < 0.05$), a distance to human settlements between 2,326 and 4,650 m ($G = 203.75$, g.l.v = 5, $p < 0.05$) and a distance to steep slopes of less than 1,047 m ($G = 79.09$, g.l. = 5, $p < 0.05$) (Figure 3). Like the jaguar, pumas probably choose these areas because they are the least disturbed in the whole park thanks to their difficult access.

Human activities are the main factor limiting the distribution of pumas and jaguars in the State of Mexico. Besides sites with low human activity, pumas prefer areas with a dense canopy and underbrush and steep slopes because these habitats provide them with places to hide, stalk their prey and rest, and greater protection for their young (Belden *et al.*, 1988; Logan and Sweanor, 2001; Navarro-Serment *et al.*, 2005; Sunquist and Sunquist, 2002).

Poaching is one of the greatest problems of large felids, whether it is driven by the sale of their skin or the control of their apparent predation on livestock. Although only 13.4% of people surveyed in Sierra de Nanchititla own livestock, records of livestock killed amounted to 34 over the last 10 years. Pumas were the most hunted felids and represented 55% of reports. However, predation on livestock in this area is lower than that reported for areas in the United States, Venezuela and Brazil, among others (Logan and Sweanor, 2001; Hoogesteijn *et al.*, 2002; Crawshaw and Quigley, 2002; Navarro-Serment *et al.*, 2005; Zimmermann *et al.*, 2005; Michalski *et al.*, 2006).

Activity patterns

We obtained 126 photographs of both species in 4,305 trap days in 22 sampling sites, out of which 77 were independent records of pumas and 11 were independent records of jaguars. RAI1 and 2 were 107.2 and 0.02 for jaguars, and 52 and 0.37 for pumas respectively (Table 3). We obtained over five times more photographs of pumas than jaguars; most of them show only one individual, but pairs were recorded on two occasions –a female with a male and a female with a cub. Both species are solitary, except during the mating season and periods of juvenile dependence (Sunquist and Sunquist, 2002). The pair of adult pumas was photographed in May 2004, which suggests that the mating season in that area takes place at that time. In the case of the jaguar, the individual photographed was always the same solitary male.

Out of the independent photographs of both species, the time was only visible in 59, which were used in the activity pattern analysis. Jaguar activity was only recorded at night, and was greatest between midnight and 6:00 hrs. Pumas were active all day long, but especially between 06:00 and 22:00 hrs (Figure 4).

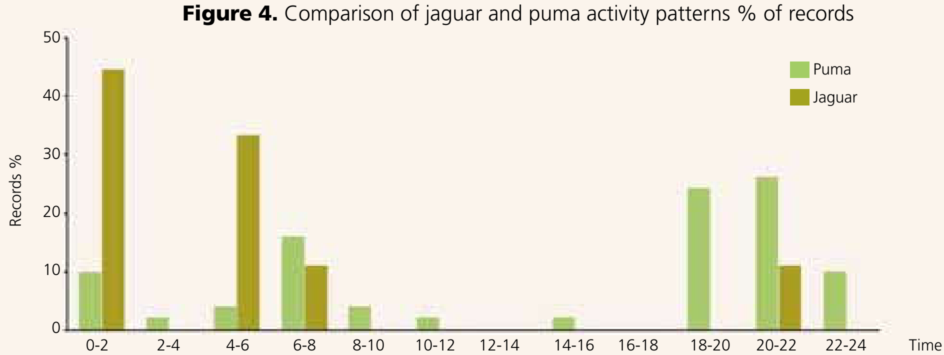
The results of the two relative abundance indices show pumas to be more abundant than jaguars in the study area. RAI1 is inversely proportional to density, whereas RAI2 is directly proportional to it (O'Brien *et al.*, 2003). The trend of the relative abundance indices obtained is probably related to absolute density, as shown by other studies (Carbone *et al.*, 2001; O'Brien *et al.*, 2003).

According to the literature, pumas have their activity peak at dawn and dusk, but they become more nocturnal in areas where timber is continually harvested (Sunquist and Sunquist, 2002), which matches our observations. Most puma records were obtained in the first hours after dark. Jaguars are mainly diurnal, which does not correspond to our observations, given that most jaguar records were obtained after midnight and before dawn (Sunquist and Sunquist, 2002). The habits of these two species greatly depend on the activity patterns of their prey. These differences are very likely to be a strategy of pumas to avoid encounters with jaguars. This behavior has often been observed in sympatric species with similar feeding habits; it seems to reduce competition and allow them to coexist (De Almeida *et al.*, 2004).

Table 3. Total number of photographs of each species

Species	Total photos	Independent photos (No.)	Min-max individuals in photo	No. of photos in daytime	No. of photos at night	RAI 1	RAI 2
Puma	106	77	1-2	21	56	54	0.37
Jaguar	18	11	1-1	0	11	107.2	0.02

Figure 4. Comparison of jaguar and puma activity patterns % of records



Perspectives for future work

The main threats to pumas and jaguars in the study area are habitat destruction due to fires, logging –legal and illegal– extensive agriculture, including livestock farming, hunting, and the lack of alternative productive activities and information about these species in this type of environment.

To conserve these species in the long term in Sierra de Nachititla and other regions of the state –and probably the country–, conservation projects must be linked to local communities through alternative productive activities with a low impact on the ecosystem, such as mushroom farming, growing vegetables in greenhouses, breeding native wildlife, and rural and cultural ecotourism, among others. Coordination with governmental activities is also necessary. Environmental education programs are also essential to provide capacity building to local people: all these activities must be included in a general management and conservation program. To reduce the impact of hunting in the area, a livestock management scheme must be implemented; it should consider measures such as keeping domestic animals in enclosures close to people. In other regions, good livestock management has been key in reducing the conflict between pumas and livestock farmers (Miller, 2002).

In the short and mid term, Sierra de Nanchititla can function as a biological corridor for jaguars. Its conservation should focus on identifying connections between breeding populations. We identified possible connections between this Sierra and southern State of Mexico, northern Guerrero and northwestern Michoacán, which have similar features to those identified as preferred by pumas and jaguars (INEGI, 2003 a, b). Some researchers argue that there are very few areas where jaguars have a high probability of persistence, and that a small number of corridor areas would create contiguous links of jaguar habitat from northern Mexico to Argentina (Chávez and Ceballos, 2006; Chetkiewicz *et al.*, 2002; Sanderson *et al.*, 2002b). In the long term, after taking measures that reduce the impact on the environment and promote a better standard of living for local people, the region could function as a reservoir for a breeding population. As regards to pumas, there is evidence of the existence of a breeding population in the area, as juvenile individuals have been recorded over the last three years. It is necessary to assess the surrounding areas to locate possible corridors that may connect it with other well preserved areas.

Acknowledgments
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STATUS OF JAGUARS IN THE REGION OF LOS CHIMALAPAS, OAXACA

Iván Lira Torres and Gabriel Ramos-Fernández

Resumen

La región conocida como Los Chimalapas en los municipios de Santa María y San Miguel Chimalapa, Oaxaca, todavía alberga una importante población de jaguar en México, probablemente debido a su notable biodiversidad, extensión e inaccesibilidad provocada por cuestiones físicas, sociales y políticas. Esta especie destaca por su importante función en la dinámica de los ecosistemas, actuando como factor regulador de las poblaciones de sus presas. Sin embargo, observaciones recientes sugieren que la especie enfrenta serios problemas de conservación en la región, y desde el año 2000 es frecuente el reporte de ganado doméstico (equinos y bovinos) depredado por jaguar en los alrededores de las comunidades y en los potreros cercanos al borde de los bosques de la región. Los resultados de nuestro estudio en la región indican que las principales amenazas a la población del jaguar son la fragmentación y pérdida del hábitat, el comercio de pieles, el mercado de mascotas y el uso indiscriminado de las especies que son las principales presas del jaguar (pecarí, agutí, venados y tapir). Este trabajo es un esfuerzo para generar una estrategia de conservación, monitoreo y uso sustentable del jaguar y sus presas en la región de Los Chimalapas.

Palabras Clave: Jaguar, Chimalapas, cacería, depredación de ganado.

Abstract

The region known as Los Chimalapas in the municipalities of Santa María and San Miguel Chimalapa, Oaxaca, mantains one of the largest jaguar populations in Mexico, probably because of its remarkable biodiversity, size and difficult access, imposed by physical, social and political factors. This species is important due to its role in ecosystem dynamics, where it acts as a regulating factor for prey populations. The species faces serious conservation problems in the region, and since the year 2000, predation on livestock (equine and bovine) has become more frequent around human settlements and pastures close to the forest edge. The results of our study in the region show fragmentation and habitat loss, fur and pet trade, and non-sustainable hunting of its main prey (peccaries, agouties, deer and tapirs), as the main threats to the jaguar population. This work is the beginning of an effort to generate a conservation strategy, monitoring work, and sustainable use of the jaguar and its prey in the Chimalapas region.

Key words: Jaguar, Chimalapas, hunting, livestock predation.

Introduction

Although Mexico is the fourteenth largest country in the world, it ranks third in biological diversity, which makes it a megadiverse country (Mittermeier *et al.*, 1997; Ramamoorthy *et al.*, 1993). However, its biodiversity is at great risk of disappearing due to anthropogenic activities. It is estimated that only 40% of Mexico's primary forest cover still remains and the annual deforestation rate is 4.2%, the highest in Central America (Challenger, 1998). Most of the biodiversity that still remains in Mexico occurs in inaccessible regions where indigenous people are predominant and poverty is still a major problem. In spite of the efforts made by a number of governmental bodies and non-governmental organizations over the last two decades, biological conservation in Mexico has become a difficult task (Caballero, 2000).

One of the priority regions for biodiversity conservation in Mexico is Los Chimalapas, in the state of Oaxaca (Arriaga *et al.*, 2000). It is a large region (590,993 ha) that has not been much explored and contains the second largest area of well-preserved tropical rainforest in Mexico, after the Maya Forest (Caballero, 2000). However, it is not included within the National System of Protected Areas, and, although community conservation areas are being established, there is still a strong pressure over its natural resources (Cid, 2001).

Wild animals in the region are a source of income or food for the human population, but hunting practices are not sustainable and pose a threat to long-term ecological and economic benefits provided by such animals. An example of this is the conflict due to predation on livestock –horses and cattle– by wild carnivores in the region of Los Chimalapas, as a consequence of the decline in the populations

Figure 1. Regions in the study area; municipalities of Santa María and San Miguel Chimalapa, Oaxaca.

of their natural prey. Predation caused by jaguars carries a greater risk and financial impact than those caused by other carnivores. When livestock farmers do not receive support from the government to protect their livestock, they are often forced to hunt the predators (Cid, 2001; De Avila, 1999; Naranjo, 2002; Schiaffino *et al.*, 2002).

Although Los Chimalapas probably contains one of the largest populations of jaguars (*Panthera onca*) in Mexico, this has not been well documented yet. This study is a first effort to collect the information available on the jaguar in this vast region. Its aim is to propose high priority strategic actions that contribute to jaguar conservation and monitoring, as well as the sustainable use of the main prey of the jaguar in the region.

Study area and methods

The study area is the region of Los Chimalapas, in the state of Oaxaca. It includes the municipalities of Santa María and San Miguel Chimalapa, which cover 458,086 and 132,907 ha respectively (Figure 1). This area represents about 7% of the surface of Oaxaca and has a population close to 12,000 people, less than 1% of the total population of the state (Gobierno del estado de Oaxaca, 1990).

The region is estimated to contain more than 462,945 ha (78.3%) of well-preserved natural systems of different types, such as tropical evergreen forest, tropical deciduous forest, cloud forest, conifer forest and oak forest (Torres Colín, 2004; Figure 2). These systems are extremely rich in animals and plants, and have many endemic species (Caballero, 2000; Briones-Salas and Sánchez-Cordero, 2004; Government of the state of Oaxaca, 1990; González *et al.*, 2004).

The study involved 12 months of fieldwork, distributed between August 2003 and July 2004. We used three main sources of information: 1) review of publications and search in databases of domestic and foreign biological collections; 2) visits to sites with and without reports of jaguar presence by local people. In each visit we

Figure 2. Cloud forest in Los Chimalapas, Oaxaca.

looked for reliable evidence of jaguar presence (scats and tracks), examined remains of prey in different sites of the region and collected skulls and skins of individuals killed; and 3) interviews with residents of communities near the area potentially occupied by the jaguar.

We had informal conversations and conducted two kinds of interviews on jaguar sightings: semi-structured interviews (Furze *et al.*, 1996; Figure 3) and short interviews. Local authorities in the communities we visited helped draw up a preliminary list of people with experience as hunters. The list of people grew as the interviews were being conducted, and we included people considered to be key informants about the status of jaguar in the region (Furze *et al.*, 1996). The semi-structured interviews followed the model shown in Annex I and were aimed at getting informants to respond to all the concepts included in the model, giving them freedom to include any other topics. This model was used to compile qualitative information provided by local people about the jaguar's historical range, biology, threats and traditional uses.

Short interviews on current and historical jaguar sightings were systematically conducted with all the people living near potential jaguar areas. The interviews included the following questions: Have you ever seen a jaguar? 2) When (date and time) and where did you see it? 3) How many animals did you see? 4) What were the animals doing when you saw them? Reports providing a physical description of the animal without the need of a picture or drawing were considered reliable. Informal conversations included all conversations with local people about issues related to the current or historical status of the jaguar and the animals of the area without following a pre-established model.

Figure 3.
Interview with a hunter in Ejido El Porvenir, municipality of San Miguel Chimalapa.
Photo: Iván Lira-Torres

Results and discussion

We compiled 12 records of jaguar presence in Los Chimalapas. Eight records (66%), were obtained in the visits to the region and based on the following evidence: tracks, scats, claw marks on trees, remains of prey and an examination of injuries caused to livestock in several sites, as well as the collection and photographs of skins of hunted jaguars (Figure 4 a, b, c and d, Figure 5 a, b). We only obtained one record (8.3%) in the databases of domestic and foreign biological collections.

We only found three publications that mentioned the specific sites where jaguar records were obtained in the state of Oaxaca (Goodwin 1969; May, 1981; Leopold, 1965). These historical records are restricted to southeastern Oaxaca, in Juchitán and Tehuantepec. Jaguar occurrence in Los Chimalapas was confirmed on the basis of a review of records in collections, field visits, interviews, tracks and the collection of specimens. Although the area is considered as a high-priority terrestrial area by Conabio, the Mexican National Commission for the Knowledge and Use of Biodiversity (Arriaga *et al.*, 2000), it does not have any protection in the Protected Area System (ANP) of the Ministry of the Environment and Natural Resources (Semarnat) National Commission for Protected Areas (Conanp).

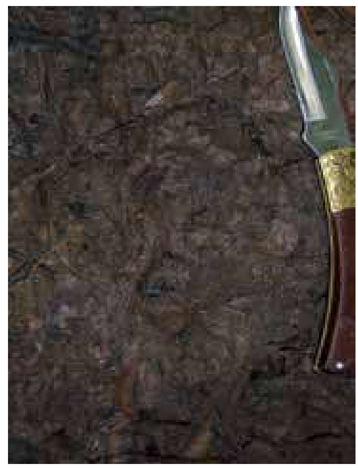



Figura 4. Evidence of jaguar presence in Los Chimalapas, Oaxaca. Top: jaguar marks on tree in study area; center and bottom; jaguar tracks in study area; bottom left: adult cattle killed by jaguar, showing a skull fracture.
Photos: Iván Lira-Torres

Considering the estimate of 1 jaguar/15 km^2 reported for Calakmul Biosphere Reserve (Ceballos *et al*., 2002), and given that the region comprises 4,629 km^2 of well-preserved habitat, Los Chimalapas was estimated to have a population of 309 jaguars (Table 1).

Figure 5. Skins of jaguars hunted in Los Chimalapas, Oaxaca. Top: skin of adult male hunted in Santa María; bottom: skin of young male hunted in San Miguel.
Photos: Iván Lira-Torres

A minimum number of 50 breeding individuals has been proposed as necessary to prevent a population from having problems due to loss of genetic diversity; a minimum number of 500 is considered to guarantee long-term conservation (Aranda, 1996). The variety of natural systems, low level of disturbance and isolation of Los Chimalapas suggest that this region may contain one of the largest jaguar populations in Oaxaca, which would make it one of the populations with the greatest chances of persisting in the long term.

The main threats to the survival of jaguars in the region are habitat loss or degradation, subsistence hunting, public unrest in the state and the development of infrastructures (Table 2; Figure 6). On the whole, the interviews showed that livestock depredation by jaguars reflects an imbalance in the local ecosystem. Under natural conditions and with its natural prey species available at natural levels, felids do not usually attack livestock. If they live in suitable areas with enough prey and little or no human influence, they tend to avoid humans and their domestic animals (Almeida, 1986). The lack or decline of natural prey due to subsistence hunting or diseases spread by domestic animals may be the cause of attacks in intermediate areas between conservation units and livestock farming areas (Bowland, 1992).

Human persecution of large felids because of livestock predation or the potential danger they represent to human lives is the last stage in the process of their disappearance outside protected areas (Nowell and Jackson, 1996). Persecution even takes place within protected areas, so jaguars survive in inaccessible places where they are difficult to hunt. This is the case of Los Chimalapas, its ruggedness has contributed to maintaining jaguar populations but also makes it difficult to study them *in situ*.

Table 1. Estimate of the size of jaguars population in Los Chimalapas, Oaxaca							
Site	Region	Area in km²	Habitat types present	Low density (1 jaguar/20 km²) **	Conservative estimate of density (1 jaguar/15 km²)*	Connectivity	Population viability (≤50 adult individuals)
Los Chimalapas (Municip. of Santa Maria and San Miguel Chimalapa)	Sierra Madre del Sur in Oaxaca and Chiapas	4,629	Tropical rainforest, cloud forest, tropical deciduous forest	231	308	Uxpanapa, Selva El Ocote Biosphere Reserve, Sierra Madre de Chiapas	High conservation priority in Mexico and Central America
Total # jaguars				231	308		

Table 2. Main threats to the long-term survival of jaguars in Los Chimalapas, Oaxaca	
Threat	**Number of surveys**
Habitat loss and/or degradation	40
Subsistence hunting	40
Competition with introduced species	10
Public unrest	5
Development of infrastructure	1
Other economic activities	1
Medicinal uses and pet trade	3

Figure 6. Hunting of potential jaguar prey in Los Chimalapas, Oaxaca.
Photo: Iván Lira-Torres

In fact, poor management of livestock health, the presence of diseases such as brucellosis and leptospirosis, ecto- and endoparasites, the lack of genetic and reproductive management (Solano *et al.*, 2001) and the effect of floods, droughts and forest fires are the main factors that determine livestock production and survival, rather than jaguar predation. In Los Chimalapas, as in most places with extensive livestock farming in the Neotropics, the operations are rudimentary and herds are exposed to risks in areas that are not suitable for farming. Besides, livestock becomes almost feral, which contributes to predation and livestock theft. This is a common illegal activity in farms whose foremen, workers and neighbors are not closely watched by ranch owners and blame big cats for livestock losses (Hoogesteijn *et al.*, 1993).

Besides poor management of livestock, jaguar predation on livestock in Los Chimalapas may be due to a decline in the abundance and/or a change in the distribution of its natural prey (Polisar, 2000; 2002). Several of the most important prey species for the jaguar, such as peccaries (*Tayassu* spp.), pacas (*Cuniculus paca*), Mexican agoutis (*Dasyprocta mexicana*), white-nosed coatis (*Nasua narica*) and brocket deer (*Mazama temama*) are also the ones most consumed by local people (Cid, 2001; Ojasti, 1984). Deforestation is followed by human settlements and subsistence agriculture, using wild animals as a source of protein. Deforestation is thus an indirect factor of the decline in natural prey for the jaguar, through subsistence hunting. This leads jaguars to substitute their prey for domestic animals to cover their energy requirements. Once they learn to hunt calves or young cattle, they devote their efforts to this (Rabinowitz, 1986).

Apart from being affected by deforestation and subsistence hunting, the status of jaguars is worsened because it is occasionally hunted. Local people who carry guns usually shoot any felid they see because they consider them a threat. Many animals are left injured, maimed and thus unable to hunt their natural prey, which leads them to target livestock, more abundant and easier to hunt (Schaller, 1996). This was observed when examining two specimens hunted in the communal land of La Fortaleza, municipality of Santa Maria Chimalapa and Ejido El Porvenir, municipality of San Miguel Chimalapa. In general terms, residents of these areas said jaguars repeatedly attacked and killed their livestock, so they decided to solve the problem by killing jaguars. The necropsy of the hunted specimens showed that one of them –the one hunted in La Fortaleza– had injuries, scars and gun pellets encapsulated near the cervical region, as well as a broken lower left canine. This suggests that it had had previous encounters with humans and was injured on several occasions. The jaguar in Ejido El Porvenir was hunted because it also killed livestock, according to the locals. However, the necropsy did not show previous scars and the animal was young, so it may have been killed in a casual encounter.

This situation is similar to that documented by Rabinowitz (1986), who observed that 75% (10-13) of the skulls of the livestock-attacking jaguars he examined had old scars caused by gunshots. Out of 65 jaguar skulls examined in Venezuela, 19 belonged to livestock predators; 10 (53%) of these skulls had previous scars of shotgun or rifle shots, and fragments of lead bullets incrusted in the bone, causing damage to their vision and teeth (Hoogesteijn *et al.*, 1993). This evidence shows that some problem jaguars are the result of the bad practices and activities of some farmers, who do not manage their livestock properly and shoot carnivores opportunistically.

Among the general management measures aimed at reducing the effects of predation, three main aspects have been considered (Hoogesteijn *et al.*, 1993): 1) the control of problem jaguars that predate on livestock; 2) the shift from extensive to intensive livestock farming using electric fences to optimize production and feeding cattle with fodder, 3) mechanisms to compensate farmers for losses caused by jaguars. It is important to mention that eliminating jaguars is a palliative treatment of the symptoms but does not solve the causes of the problem in any case (Rabinowitz and Nottingham, 1986; Schaller, 1996).

In general, jaguars and humans can coexist, and several communities in the north east of the municipality of Santa María Chimalapa are a clear example of this. It is important to say that jaguar predation in these areas is partly caused by the hunting pressure on potential jaguar prey, especially in forest areas that were cleared to be transformed into pastures, with introduced grass and crops.

Perspectives for future work

To determine the status of jaguars in Los Chimalapas, we propose a long-term project using three assessment methods, according to the recommendations issued in the Symposium "The Mexican Jaguar in the 21st Century" (Chávez and Ceballos, 2006):

1) Camera trapping, which will start an early warning program on the current status of jaguars in the area; it will also be used to monitor the impact of the management measures mentioned below.

2) Develop a program to assess and monitor subsistence hunting through the sustainable management of potential jaguar prey by the community.

3) Promote and conserve the large habitat fragments that still exist in the area; create and maintain strips of natural vegetation along the edges of streams and rivers, around lagoons, pastures and crops adjacent to large forest areas in the ejidos in the north east of Santa María Chimalapa. This measure will contribute to a flow of animals between forest patches, which will provide natural prey to jaguars and reduce livestock predation. The results of the camera trapping study will also be used to identify the forest patches and corridors used by wildlife and optimize conservation efforts (Medici *et al.*, 2006). This project will provide elements to help solve jaguar-livestock and jaguar-hunting conflicts, as a first step in the jaguar conservation strategy of Los Chimalapas in the state of Oaxaca.

CURRENT STATUS OF JAGUARS IN CHIAPAS

Epigmenio Cruz, Gabriela Palacios, and Marcelino Güiris

Resumen

La pérdida de hábitat por las actividades humanas representa la mayor amenaza para la supervivencia y conservación del jaguar (*Panthera onca*) en Chiapas. La especie se distribuía en casi todo el estado de Chiapas, pero actualmente sólo persiste en las principales áreas naturales protegidas y zonas adyacentes. Para las comunidades de esa zona el jaguar representa un enemigo a sus intereses y patrimonio, por el ataque real o imaginario a los animales domésticos. Durante varias décadas el Instituto de Historia Natural y Ecología de Chiapas ha realizado estudios sobre la distribución, abundancia, uso de hábitat, hábitos alimentarios, parásitos, microbiología, genética, los conflictos hombre-jaguar, así como diferentes aspectos de la vida en cautiverio. Se ha documentado que en la Sierra Madre de Chiapas el jaguar consume más de 20 especies de las cuales los principales son el *Tayassu tajacu*, *Cuniculus paca*, *Tapirus bairdii*, *Philander opossum*, *Tamandua mexicana* y *Nasua narica*. Los animales domésticos representaron el 2% de 45 excretas analizadas. En Chiapas hay más de un millón de hectáreas de tierras protegidas como reservas de la biosfera en las que es posible encontrar al jaguar; sin embargo, en algunas de ellas la fragmentación y el aislamiento representan una seria amenaza para su permanencia y conservación a mediano plazo. Durante más de 9 años de registro de datos de la presencia y distribución de la especie, en la Sierra Madre se ha obtenido una abundancia de 0.007 rastros/km para El Triunfo y de 0.013 rastros/km para La Sepultura. Se aprecia una tendencia muy ligera al aumento de la abundancia en la Sierra Madre, sin embargo, las presiones son cada vez mayores.

Palabras clave: áreas naturales protegidas, conflicto humano-jaguar, hábitos alimienticios, especies presa.

Abstract

In Chiapas as in many parts of Mexico, the habitat loss resulting from diverse human activities, represents the main threat to the survival and conservation of jaguars. Species were distributed in almost the whole state of Chiapas, but at the moment it can be found in the main natural protected areas and the adjacent areas. For the communities, jaguars represents an enemy to their interests and patrimony because the real or perceived attacks to his cattle. During several decades, the Institute of Natural History and Ecology has been carrying out different studies and work with the species. These include distribution, abundance, habitat use, diet, ecto and endo parasites, microbiology, genetics and the conflicts *man-jaguar. It has also studies on captive animals. The presence of some species of Nematodes, Cestodes and Protozoa, as well as different species of Bacteria has been documented. Results show that in the Sierra Madre de Chiapas the main prey species on the diet of this felid are,* Tayassu tajacu, Cuniculus paca *and* Tapirus bairdii, *followed by* Philander opossum, Tamandua mexicana *and* Nasua narica*; however, a total of 20 species have been confirmed to be part of their diet, including domestic animals, which represent 2.22% of 45 analyzed feces. Chiapas has over a million hectares of protected areas as Biosphere Reserves, where jaguars can be found, however, some of them are isolated and fragmented, which represents a threat for the long-term persistence and conservation of the species. For more than 9 years of study, on the presence and distribution of the species in the Sierra Madre, an abundance of 0.007 tracks/km has been obtained for El Triunfo and 0.013 track/km for La Sepultura. A very slight increase in abundance is suggested in the Sierra Madre; however, the pressures increasing.*

Key words: diet, human-jaguar conflict, natural protected areas, prey species.

Introduction

In Chiapas as in many parts of Mexico and Latin America, habitat loss, the expansion of the agricultural frontier and hunting are the main threats to the survival of jaguars. Forest fires destroy jaguar habitat every year; on average, 27,283 ha were lost every year between 1995 and 2002; the figure increased to 67,355 ha in 2003 (INEGI 2005). The jaguar used to be broadly distributed in practically all the habitat types of the state, from mangroves at sea level to cloud forests (Álvarez del Toro, 1977; Aranda and March, 1987). These habitats have suffered major changes which have pushed jaguars to find its last refuge in protected areas (Figure 1).

One of the aims of the Natural History and Ecology Institute of Chiapas (*Instituto de Historia Natural y Ecología de Chiapas*) is to explore the distribution, abundance, current status and problems of jaguars, as well as different biological, ecological and social aspects regarding the species in the state. To this end, the Institute has carried out various *in situ* and *ex situ* studies focused on reproductive aspects, diet, breeding, behavior, management and biomedical issues.

Methods

Captive jaguars in Miguel Álvarez del Toro Zoo (ZooMAT) were offered different species and parts of the same ones as food to determine what diet leads to good physical condition, a healthy looking coat, and a good reproductive condition. Jaguars were given live prey once a week. Scats were collected for parasitological and microbiological tests. A description and more details of the methods, procedures and tests can be found in Bastard (2003), Jiménez (2003) and Moreno (2003).

Ex situ

Data for the study were collected over more than 9 years. Field visits involved monthly 8-to-10-day transect walks in El Triunfo and La Sepultura Biosphere Reserves, in the Sierra Madre de Chiapas. The transects had different lengths and widths. Work was divided into three parts:

a) *Fieldwork:* The transect walks took place in the morning and part of the afternoon (from 07:00 to 16:00-17:00 hr); all jaguar scats found were collected, and collection data were recorded. Other signs of jaguar presence –tracks, remains of prey and resting places– were also recorded, with a criterion confirming the truthfulness of records. The difference in scat diameter was also recorded, based on field experience.

b) *Laboratory work:* The scats were analyzed using the technique proposed by Korschgen (1948) and Chinchilla (1997) and modified by Cruz (2001) it consists of dehydrating or drying all the scats in the sun, weighing them in a top loading balance, and washing them in a bowl with running water. After this, a 12 to 20 thread mesh strainer was used to separate the larger contents of the scat and dry them at room temperature on absorbent paper. Once the strainer was dry, it was covered with a nylon stocking to collect the smaller components that remained in the bowl and continue the drying process. When this material was dry, the contents of each sample were separated based according to their structure –hair, claws, teeth, bones, feathers and plant material– for subsequent identification.

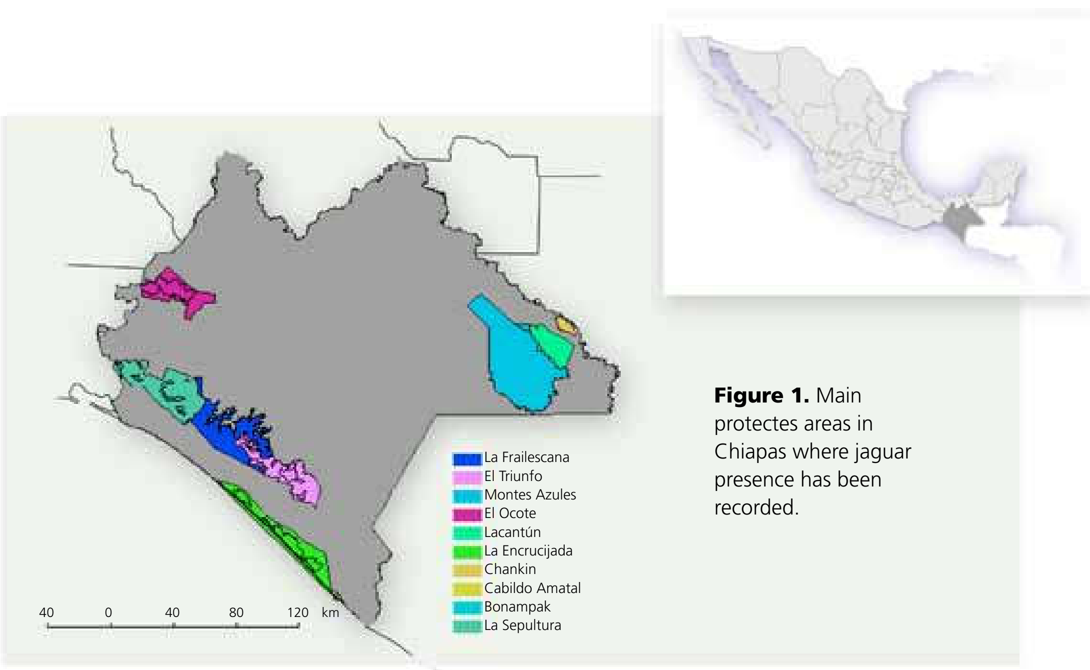


Figure 1. Main protectes areas in Chiapas where jaguar presence has been recorded.

Items found in the samples were identified at ZooMAT with the support of the material held in the scientific collections of mammals and birds of the Natural History and Ecology Institute. The collection of hair and other bony structures (nails, claws, hoofs, skin, teeth and feathers, among others) deposited in the research unit at ZooMAT was also used.

d) Data analysis: Records obtained were included in a database with the following information: species, reserve, season (wet or dry), transect, type of habitat, and weight. A one-way analysis of variance (ANOVA) was conducted to compare species, areas, prey, and seasons (wet and dry) using Microsoft Excel. Habitat use and preference were obtained from the percentage area occupied by each type of habitat in the study area and the number of scats and other traces recorded, using Habuse 4.0 (Byers *et al*., 1984).

We calculated the relative frequency of each of the prey species in the diet and estimated relative biomass using the following formulas (Chinchilla, 1997):

$$FA_i = \frac{\text{\# of samples in which prey } i \text{ was found}}{\text{total \# of samples}}$$

BER = minimum # of prey X mean body weight of each specific trophic category

The estimated weight of each prey was taken from the records of the database kept by ZooMAT.

Results and discussion

The captive jaguars in the zoo were given horse, chicken, and rabbit meat, as well as some wild animals; they were fed live prey once a week to allow them to hunt, stay active and improve their digestion and bowel transit. The captive jaguars were in good condition, looked healthy and were considered fit for breeding.

The gastrointestinal parasites recorded in scats of captive and wild jaguars in Chiapas are shown below.

Nematodes: *Strongyloides* sp., *Toxocara cati*, *Toxocara mystax*, *Toxocara leonina*, *Uncinaria* sp., *Ancylostoma* sp., *Physaloptera* sp., *Capillaria aurophila* and *Capillaria* sp.; cestodes: *Taenia* sp., *Diphyllobothrium* sp. and *Paragonimus* sp.; protozoans: *Eimeria* sp., *Cryptosporidium* sp., *Isospora felis* and *Isospora rivolta*. On a microbiological level, bacterial species reported include *E. coli*, *Enterobacter cloacae*, *Proteus vulgaris*, *Kloivera* sp. and *Clebsiella* sp. (Bastard, 2003; Jiménez, 2003; Moreno, 2003).

In situ

We analyzed different aspects of jaguar ecology, such as current distribution, abundance (Juárez, 2002), habitat use, feeding habits, parasites, microbiology, and human-jaguar conflicts. We also started population genetic studies based on scat analysis. Additionaly, we explored the population ecology of the species in different sites of Chiapas –mainly protected areas– and areas that are not protected but whose vegetation is well preserved. Surveys of different parts of El Triunfo and La Sepultura have shown that jaguar populations are increasingly affected by human activities, such as hunting, crop and livestock farming, deforestation, fires and the development of new human settlements.

State government programs are proposing different alternatives to 'improve the living conditions of communities' at a high environmental price. Some imply clearing large areas of primary vegetation to grow forest species that occur naturally in the area. Others propose introducing domestic animals without any previous assessment, technical advice or appropriate support to ensure effective practices. Moreover, Chiapas has a constant movement of groups looking for land to settle in temporarily or permanently, which results in the clearing of large areas of primary vegetation that are of vital importance for the survival of jaguars.

Jaguars and their status in protected areas

The presence of the jaguar in certain areas is specifically related to the presence of biosphere reserves, particularly the ones in the Selva Lacandona (412,910 ha) and several federal reserves such as El Ocote (101,288 ha), La Sepultura (167,309 ha), La Frailescana (181,350 ha), El Triunfo (119,177 ha) and La Encrucijada (144,868 ha). The total surface protected by these reserves is close to 1,126,903 hectares (Semarnat, 2005). The jaguar is present in these areas as well as adjoining ones with considerable plant cover and high human pressure. There are conflicts with jaguars around protected areas due to predation on domestic animals.

The areas covered with vegetation that can potentially maintain jaguar populations have different characteristics regarding protection priorities and conservation actions. The Selva Lacandona not only has excellent characteristics to maintain viable jaguar populations, but is also connected to the area of Los Petenes in Guatemala and the south east of Mexico. El Ocote Biosphere Reserve also has specific features that make it an area with the potential of maintaining viable jaguar populations; moreover, its jaguar populations are connected to those of Los Chimalapas in Oaxaca and Veracruz. The populations in the south and south west of the state must also be taken care of.

According to Palacios (2005), semi-evergreen forests, pine-oak forests, grasslands and cloud forests are of great importance in the habitat use and diet preference of jaguars in the Sierra Madre (Table 1).

Table 1. Observed and expected scat frequencies of *P. onca* by habitat type in La Sepultura Biosphere Reserve

Habitat	of[1]	ef[2]	Pof[3]	Pef[4]	Confidence interval[5]
Pine forest	8	6.603	25.80	10.52	0.056-0.460 (-)
Pine-oak forest	11	20.150	35.48	32.11	0.133-0.576 (*)
Pasture	2	13.144	6.45	10.27	0.000-0.178 (*)
Semi-evergreen forest	3	4.960	9.67	15.41	0.000-0.234 (-)
Semi-deciduous forest	7	17.887	22.58	35.98	0.032-0.419 (*)
Total	**31**	**62.744**	**100**	**100**	

[1] Observed frequencies.
[2] Expected frequencies.
[3] Proportion of obs. freq.
[4] Proportion of exp. freq.
[5] Bonferroni intervals (X^2=21.300; gl=4; P>0.05)

(*) Habitat used as expected
(-) Habitat used less than expected

Isolation of protected areas

The protection of the Sierra Madre and the coastal plains of Chiapas is enough to maintain viable jaguar populations in the long term. In the reserves of La Sepultura, La Frailescana and El Triunfo, the only areas with suitable conditions for the jaguar are in the intermediate and higher parts of the Sierra (Carrillo *et al.*, this volume). La Encrucijada, in the coastal plain of Chiapas, is a fully protected area where jaguars can still be seen (Figure 1).

The presence of the species has been documented in different parts of the state through sightings, signs and predation on domestic animals (Figure 2). Records collected over more than 9 years report the presence of the species in the Sierra Madre de Chiapas. In five years of monitoring, particularly in El Triunfo, the relative abundance recorded was 0.007 signs/km in El Triunfo and 0.013 signs/km in La Sepultura. Jaguar populations seem to be experiencing a slight positive trend in the Sierra Madre in almost 10 years of monitoring (Figures 3 and 4).

Feeding habits

With the support of studies on the diet and feeding habits of jaguars, we recorded about 20 wild animal species in 45 scats analyzed (Table 2). They included the collared peccary (*Tayassu tajacu*), paca (*Cuniculus paca*), tapir (*Tapirus bairdii*), gray four-eyed opossum (*Philander opossum*), northern tamandua (*Tamandua mexicana*) and white-nosed coati (*Nasua narica*). The first three species were the most frequent, reaching similar levels to those reported by Chinchilla (1997). The analysis of species richness in the prey consumed suggests that the jaguar does not have a preferred species that forms the basis of its diet. These findings are similar to those reported by Mondolfi and Hoogesteijn (1986) and Crawshaw and Quigley (1991) in The Pantanal, Brazil, where the jaguar was found to consume larger prey.

As for livestock predation, only 2.2% of the samples analyzed contained traces

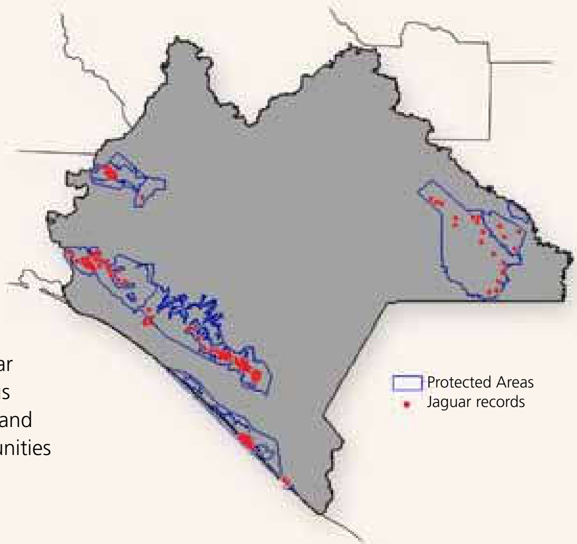
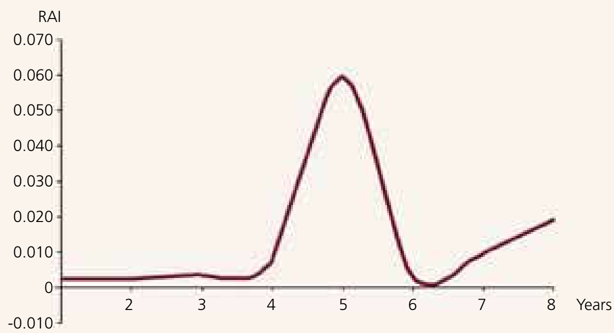
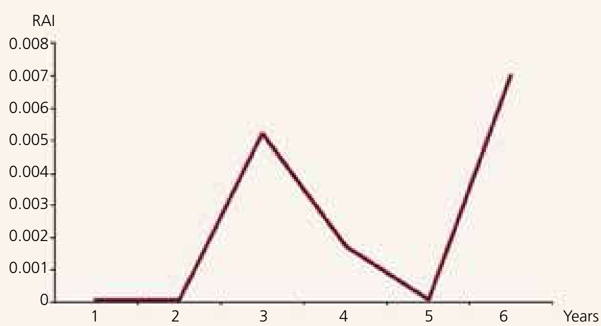


Figure 2. Jaguar records in various protected areas and adjacent communities in Chiapas.





Figures 3 and 4. Behavior of jaguar abundance and trend shown by the population in the Sierra Madre de Chiapas in over 8 years of monitoring.

Table 2. Vertebrate species identified in jaguar diet and their relative frequency of occurrence in the Sierra Madre de Chiapas

Species	Frequency
Cathartes aura	0.02
Caluromys derbianus	0.02
Didelphis virginiana	0.02
Philander opossum	0.09
Dasypus novemcinctus	0.07
Tamandua mexicana	0.09
Canis latrans	0.02
Bassariscus sumichrasti	0.07
Nasua narica	0.09
Tapirus bairdii	0.11
Tayassu tajacu	0.27
Mazama temama	0.07
Odocoileus virginianus	0.07
Sciurus depeii	0.02
Sciurus aureogaster	0.02
Cuniculus paca	0.11
Bos taurus and *Bos indicus*	0.02
Equus caballus	0.02
Unidentified mammal	0.04
Unidentified rodent	0.02

of bovine and equine livestock (Palacios, 2005). These results prove that the jaguar does not have a direct or intense impact on domestic animals. However, the fact that puma and jaguar attacks on livestock are periodically reported seems contradictory. The results obtained in this study show that jaguars are not the only animal to blame for the death and loss of livestock; pumas also occur in these areas and may be responsible for some of these deaths (Palacios, 2005).

For 16 years, jaguars have been documented to kill an average of 18 livestock a year, which amounts to a total number of 295 animals (horses, sheep and cattle) in ejido Adolfo López Mateos, in Arriaga, La Sepultura Biosphere Reserve. Workshops have been organized to improve the relation of landowners with the jaguar and reduce conflicts. In La Sepultura, the damage seems to be relatively severe in at least three ejidos (López Mateos, Tierra y Libertad and Tiltepec), where jaguars and pumas are affecting the resources of local people. These communities have agreed to gradually replace their livestock operations by alternative options that contribute to jaguar conservation.

Even though it is still relatively easy to find jaguars in Chiapas, their distribution is increasingly restricted to high mountain areas. Governments, authorities, scholars and society must therefore join efforts both to conserve the species and to find a better way of life for rural communities. These efforts must combine and satisfy the interests of the species and the human populations to conserve jaguars in Chiapas and Mexico.

Perspectives

This study provides important information about the threat human activities represent for the survival of jaguars in Chiapas and the threat posed by jaguars to the interests of human populations and their livestock. Our findings can be used to guide actions that protected areas, and governments must consider conserving the species and its habitat.

It is important to intensify and extend the sampling effort to a greater number of sites in Chiapas to document the current status of jaguars in the state, and implement other monitoring and marking methods. Existing issues between human and jaguars must be dealt with, taking claims into account and trying to find solutions or mitigation measures that reconcile human interests and jaguar conservation. Committees should be set up and involve, at least, representatives of society, scholars, conservation institutions and governments.

Acknowledgments

This study was carried out with the unconditional support of the Instituto de Historia Natural y Ecología (IHNE) and the Zoológico Regional Miguel Álvarez del Toro. We would like to thank the Polyclinic and Veterinary Diagnostic Laboratory; the authorities of the protected areas in Chiapas, especially El Triunfo, La Sepultura, El Ocote and La Encrucijada Biosphere Reserves for their support; the team working on the IHNE project Endangered Mammals of Chiapas; D. Eduardo Espinosa Medinilla and all the people who have contributed in any way to obtaining field data for jaguar conservation.

POPULATION ECOLOGY OF JAGUARS AND ITS IMPLICATIONS FOR CONSERVATION IN THE YUCATAN PENINSULA

Cuauhtémoc Chávez, Gerardo Ceballos, and Miguel Amín

Resumen

El jaguar está en peligro de extinción en México. La Península de Yucatán mantiene la mayor extensión de selvas en el país, que enfrentan amenazas severas para su mantenimiento a largo plazo. Aunque se estima que las selvas de las península mantienen a una población de jaguar numerosa, no existe información actualizada sobre su situación actual. El objetivo en este trabajo fue desarrollar un diagnóstico general de la situación del jaguar y sus prioridades de conservación en la Península de Yucatán, con base en estudios llevados a cabo en la Reserva de la Biosfera Calakmul en Campeche y en el Ejido Caoba en Quintana Roo. El área de actividad del jaguar fue de 56 km^2, pero en algunos machos alcanzó hasta 1,000 km^2. La densidad varió de 3.3 a 6.6 individuos por 100 km^2. El tamaño estimado de la población en Calakmul es de cerca de 900 jaguares, y el de toda la península probablemente mayor de 2,000 ejemplares. La evaluación del efecto de la cacería de subsistencia sobre las presas en Calakmul indicó que se traslapa con las presas del jaguar y el puma, por lo que se estima que tiene efectos negativos severos. Aún existe la posibilidad de mantener la mayoría de las selvas remanentes de la Península de Yucatán, que requiere de acciones concretas para su mantenimiento a largo plazo. Estas tendrán que darse a diferentes niveles, desde los pobladores locales hasta las autoridades gubernamentales. El papel de los científicos es proveer de bases sólidas para lograrlo, y darle pertinencia social a nuestro trabajo.

Palabras clave: jaguar, uso del hábitat, conservación, reservas, Calakmul, Península de Yucatán.

Abstract

Jaguars are an endangered species in Mexico. The Yucatan Peninsula maintains the largest extension of tropical forests in the country, facing threats for their long term maintenance. Although the Peninsula has an important jaguar population, there is no updated information about its current situation. The objective of this work was to develop a general evaluation of the jaguar status and their conservation priorities.in the Yucatan Peninsula, based on the studies conducted in the Calakmul Biosphere Reserve in Campeche, and in the Ejido Caoba in Quintana Roo. The jaguar's home range was 56 km^2*, some males ranged up to 1,000* km^2*. Density ranged from 3.3 to 6.6 individuals per 100* km^2*. The estimated popu-*

lation size in Calakmul around close to 900 jaguars, and for the whole Peninsula it was around 2,000 individuals. The evaluation of the effect of subsistence hunting on the jaguar population of Calakmul showed an overlap with puma and jaguar prey, thus estimating severe negative effects. There is still time to maintain the most of the remnant forest in the Yucatan Peninsula, which requires concrete conservation actions, at all societal levels from local inhabitants to governments. The role of scientists is to provide the scientific basis to achieve it.

Keywords: jaguar, hábitat use, conservation, reserves, Calakmul, Yucatan Peninsula.

Introduction

Jaguars (*Panthera onca*) are endangered in Mexico because of factors such as the destruction of natural ecosystems and poaching, which have led to a decrease in jaguar populations and a reduction of the species' range (Quigley and Crashaw, 1992; Medellín *et al.*, 2002; Sanderson *et al.*, 2002c). In an effort to protect jaguars and other tropical species facing conservation risks, the Mexican government established Calakmul Biosphere Reserve in Campeche and Bala'an Ka'ax Flora and Fauna Protection Area, and the government of Campeche established two adjoining State Reserves to Calakmul – Balam Kin and Balam Ku. These reserves protect more than a million hectares of relatively well-preserved tropical forest. Outside the reserve there are more than one million additional millions– hectares that are important for the conservation of jaguars and regional biological diversity. However, habitat destruction and transformation are a threat to the jaguar and thousands of other species. It is necessary to design a jaguar conservation strategy based on a diagnosis of the biological and ecological variables that affect its survival and of the social reality of the Maya Forest in southern Campeche and Quintana Roo. The objective of this study is to produce a general assessment of the status of jaguars and establish conservation priorities for the species in the Maya Forest.

Methods

The study was conducted in the south of the Yucatan Peninsula: Calakmul Biosphere Reserve in Campeche and Ejido Caoba in Quintana Roo (Figure 1). The dominant vegetation in this region is tropical rainforest and semi-evergreen forest, and –to a lesser extent– tropical deciduous forest and seasonally flooded forest (Semarnat *et al.*, 2001). The main economic activities in the ejido are forest exploitation and crop and livestock farming. Although hunting is not permitted in the timber exploitation area, it is common practice. The ejido is home to 1,322 people, who live in two villages (INEGI, 2005). The Calakmul region has one of the largest remaining areas of Mexican tropical forest (Martínez and Galindo-Leal, 2002). It is basically flat, with an elevation ranging from 100 to 3,000 masl, and has sub-humid tropical climate, with a mean annual temperature of 24.6° C and considerable seasonal changes. The wet season lasts from June to November, and mean annual rainfall is 1076.2 mm (Turner II *et al.*, 2001). About one third of the region is flooded during the wet season. There are virtually no permanent rivers or streams in the Calakmul region (Semarnat, 2000).

Additionally, we assessed connectivity between Caoba and Calakmul region and other regions in the east and north of the Yucatan Peninsula. This region includes 7 high-priority terrestrial areas for the National Comission on Biodiversity (Conabio): Petenes-Ría Celestum, Dzilam-Ría Lagartos-Yum Balam, Río Hondo, Silvituc-Calakmul, Sur del Punto PUT, Zonas forestales de Quintana Roo, and Sian Ka'an-Uaymil-Xcalak (Arriaga *et al.*, 2000). The region is characterized by a virtual lack of permanent rivers or streams. Although one third of the region is flooded during the wet season, water is only available in small bodies of water called "aguadas" in the dry season (Gómez-Pompa and Dirzo, 1995; Semarnat, 1995).

Jaguars were captured in the dry season –January to June– from 1997 to 2006. After anesthetizing the animals with a blowgun (Teleinject Inc), they were fitted with a VHF or GPS radio collar with VHF transmitters. For more details on methods, see Ceballos *et al.* (2002) and Chávez (2006). To assess the density of jaguars and their prey, we used 20, 35 mm (CamTrakkerTM) photographic cameras. The sampling work only took place in the dry season, to avoid heavy rains and accessibility problems. Between May and June 2002, we placed the cameras in four 8-kilometer

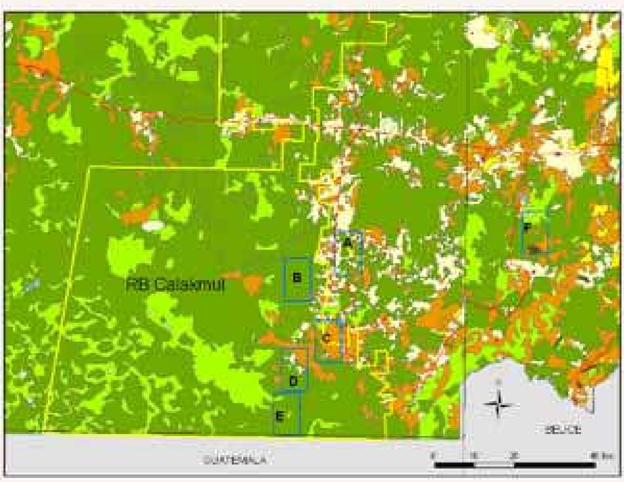


Figure 1. Geographic location of the ecological study area. It shows the sites where scat sampling and the jaguar and puma radio telemetry study were conducted in the Maya Forest. The sites were Costa Maya in Calakmul Biosphere Reserve (B) and Ejido Caobas. Scat sampling took place in Gallinero (E), Altamira (D), Narciso Mendoza (A) and Once de Mayo (C).

paths at 2 km intervals, covering an area of 48 km^2. The cameras were active for 30 days in each site (in Ejido Caoba and Calakmul Biosphere Reserve). Between April and June 2003, we randomly established eight 1 km^2 cells on a area of 49 km^2. We placed five photographic cameras in each cell, four at the corners and one in the centre, separated by a distance of 333 m. The cameras were active for 14 days in each station.

We assessed the feeding patterns of the jaguar (*Panthera onca*) and puma (*Puma concolor*) and their relation with prey availability in Calakmul and Caoba. In Calakmul, scats were collected in Costa Maya from 1997 to 2000 and in Costa Maya, Altamira-Villa Hermosa and El Gallinero in 2000 (Figure 1). In Ejido Caoba, scats were collected in the village of Caoba, San José and the forest area from 2001 to 2004. The source of each scat was determined through an analysis of fecal bile acids, a considerably reliable technique that distinguishes jaguar from puma scats because puma scats leave a stain of deoxycholic acid on chromatography plates (Amin, 2004; Cazon and Suhring, 1998).

In the Costa Maya area, prey availability was determined by walking transects in two sampling designs in 1999-2000. The first design consisted of a 60 km^2 rectangle divided into 60, 1 km^2 cells, 5 of which were randomly selected. The second design involved selecting five linear 5 km sections in a 32 km dirt track. Sampling took place at dawn –05:00 to 07:00 hrs– and dusk –17:00 to 19:00 hrs–, the periods of greatest activity for mammals, in new moon and last quarter moon. For more details on methods, see Amín (2004).

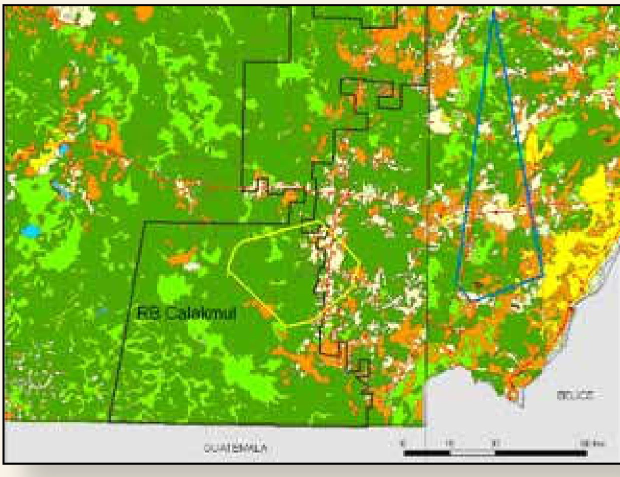
Results and discussion

Movements and population density

We captured 34 jaguars and 8 pumas between March 1997 and June 2006. In 2001 a jaguar was fitted with a GPS for the first time ever in Ejido Caoba. Another 12 animals were fitted with GPS collars after this. We obtained 20 to 350 readings per year. In 2005 we fitted the first 4 GPS satellite radio collars, which produced more than 1,000 location data for 6 months or more.

The home ranges recorded were very variable. This was probably due to a combination of the logistics needed to follow the animals and their habitat requirements. In Calakmul Biosphere Reserve, the average home range determined with VHF radio collars was 56 km^2 for jaguars and 133 km^2 for pumas. Satellite radio collars showed a home range of more than 1,000 km^2 for two males known as Tony and Lico in Costa Maya and Caoba respectively (Figure 2). Home ranges were greater for males than females. The home range of the male known as Lico overlapped with those of several females, who moved 133 km^2 on average (Figure 3).

The camera traps recorded one jaguar in Costa Maya and two in Caoba (Figure 4). Capture frequency was 4.6 jaguars in Costa Maya and 3.3 jaguars in Caoba. Based on



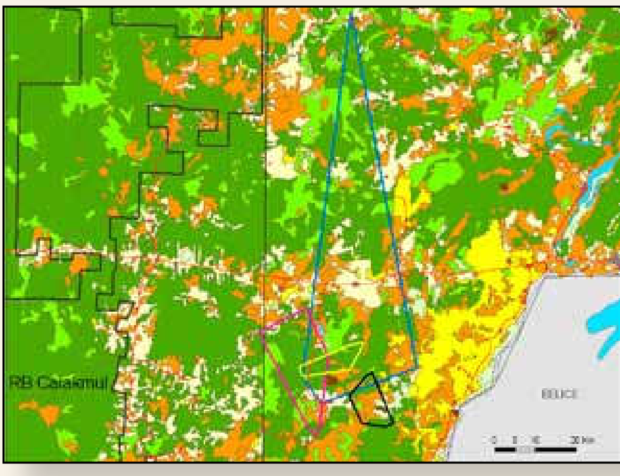


Figure 2. Home ranges of two males, one in Calakmul Biosphere Reserve (Tony, in yellow) and one in Ejido Caobas (Lico, in blue).

Figure 3. Home ranges of Lico, a male (blue) and three females (Melissa, Dalia and Verónica) in Ejido Caobas.

Figure 4. Jaguar photographed with a camera trap in Ejido Caobas.

the results of both methods –radio telemetry and camera trapping– a jaguar density of 3.33 to 6.67 individuals/100 km^2 was estimated in the study area. The initial findings of one individual/15-30 km^2 in the same region were supported by recent data (Chávez, 2010). This shows that jaguar density in Calakmul falls within the intervals recorded in other regions of the Yucatan Peninsula such as Cokscomb Basin in Belize, where density is one individual/13-16 km^2 (Rabinowitz and Nottingham, 1986), and Mexico, such as Chamela-Cuixmala Biosphere Reserve on the Pacific coast, where density was estimated at 1 jaguar/33 km^2 (Núñez *et al.*, 2000, 2002).

Jaguar prey and poaching

This section deals with feeding patterns of jaguars and prey availability for the species. Out of the 354 scats collected, it was considered that most of them (72%) were jaguar scats, 20% were puma scats and 8% could not be determined. Both species consumed 76% of the mammal species present in the area and reported in literature as prey (Amín, 2004). Seventeen mammal species of seven orders were identified in jaguar scats, whereas only 12 species were found in puma samples. Species only found in jaguar scats were the tayra (*Eira barbara*), northern tamandua (*Tamandua mexicana*), Red brocket deer (*Mazama temama*), cacomixtle (*Bassariscus sumichrasti*) and rabbit (*Sylvilagus floridanus*). The predominance of mammal species in jaguar and puma feeding patterns has been documented in a number of studies (Aranda and Sánchez-Cordero, 1996; Chinchilla, 1997; Dalponte, 2002; Emmons, 1987; Kuroiwa and Ascorra, 2002; Oliveira 2002; Perovic, 2002; Polisar *et al.*, 2003; Quigley and Crawshaw, 2002).

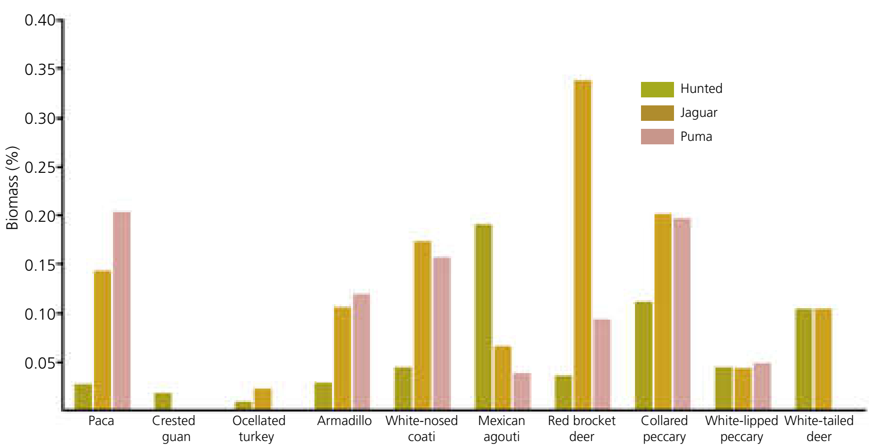


Figure 5. Biomass of the ten most important bird and mammal species for hunters in Ejido Cristóbal Colón, southern Yucatan Peninsula (Escamilla *et al.*, 2000). Data for jaguars and pumas were obtained by analyzing 45 and 15 scats, respectively.

Overlapping between jaguar and puma prey has been documented in the whole area of sympatry between both species (Oliveira, 2002). Although pumas have been postulated to have a broader diet than jaguars (e.g, Núñez *et al.*, 2000), the findings obtained in Calakmul suggest that, at least in the Maya Forest, the jaguar's diet is broader. They also show that, although both felids are opportunistic, they have preferences for certain size categories (Amín, 2004). Jaguars were more selective and consumed species such as the collared peccary (*Tayassu tajacu*), paca (*Cuniculus paca*) and armadillo (*Dasypus novemcinctus*). The puma, however, only selected the paca (*Cuniculus paca*) and used the Central American agouti (*Dasyprocta punctata*) only in proportions close to its occurrence (Amín, 2004). Larger species such as the white-tailed deer (*Odocoileus virginianus*) and red brocket deer (*Mazama temama*) did not show great differences between use and availability (Amín, 2004).

In the Calakmul region, subsistence hunting has severe effects on jaguar and puma prey, as there is considerable overlap between the most common prey of felids and human hunters (Figure 5). In jaguars and other species, the disappearance of prey has been documented to have a potential direct impact on population size and density (Bodmer, 1995; Johns, 1988; Peres, 1990). In extreme cases, there are forests where the vegetation is well or very well preserved, but there are no populations of the favorite species of hunters and thus large carnivores. This is known as the empty forest syndrome (Redford, 1992).

Activity patterns and habitat use

In Calakmul, jaguars are mainly a crepuscular and nocturnal, and carries out part of its activities at dawn, before the first sun rays appear through the trees. Differences were found between jaguar and puma habitat. Jaguars usually prefer areas with greater forest cover near bodies of water or riparian habitat, whereas pumas use available habitat in the same proportion. Habitat use changes in the wet and dry season, mainly because of water availability, which affects prey availability (Chávez, 2006; Chávez, 2010).

Habitat use was evaluated by means of a geographic information system (GIS) and radio telemetry data. In the Costa Maya site of Calakmul Biosphere Reserve, a preference was shown for semi-evergreen forest (60%), followed by tropical deciduous forest (25%). Percentages for males and females were very similar. In Ejido Caoba, tropical rainforest and medium semi-evergreen forests (49%) and low semi-evergreen forests (40%) were selected. Jaguars showed a preference for places where water was easily available (riparian habitat), whereas pumas did not show habitat selection (Chávez, 2006). On a regional level, jaguar and puma habitat use was similar (Zarza *et al.*, this volume).

Population size and priority conservation areas

The region of Calakmul comprises 13,717 km^2 and includes the protected areas Calakmul, Bala'an Ka'ax, Balam Ku and Balam Kim. This region is home to a jaguar population of over 700 individuals. These results show that this is the largest protected jaguar population in Mexico and one of the largest jaguar populations on the whole continent (Table 1; Figure 6). In the north east of the peninsula, additional reserves such as Ría Lagartos and Yum Balam protect a smaller jaguar population. However, there is a considerable amount of habitat outside these reserves, which leads to inferring that this region probably contains a population of over 200 jaguars (Faller *et al.*, this volume; Navarro-Servent *et al.*, this volume). Therefore, the protected areas of the Yucatan Peninsula may contain as many as 890 jaguars (Table 1).

There is an enormous amount of habitat available between the protected areas in the north east (e.g., Yum Balam), east (Sian Ka'an) and south (Calakmul) that probably contains a population of around 1,000 jaguars. Forest conversion to agriculture is the greatest threat to the region (Brown *et al.*, 2003; Zarza *et al.*, this volume). All these forests must be protected to conserve jaguars, biological diversity

Table 1. Protected areas in the Maya forest of Campeche, Quintana Roo and Yucatan, México.

Name of protected area	Area (km^2)	Potential habitat (km^2)	Population size* 6.67	Population size* 3.33
Yum Balam (1)	1540	84	5.6	2.8
Ría Lagartos (2)	604	139	9.3	4.6
Punta Nizuc (3)	26	-	-	-
A. de Puerto Morelos (4)	3340	-	-	-
Ría Celestún (5)	597	2	0.1	-
Los Petenes (6)	2832	3	0.2	0.1
Sian Ka´an (7)	5280	1687	112.5	56.2
Uaymil (8)	891	661	44.1	22.0
Calakmul (9)	7227	6040	402.9	201.1
Balam Ku (10)	4086	3585	239.1	119.4
Balam Kin (11)	996	435	29.0	14.5
Balam Ka´ax (12)	1288	711	47.4	23.7
Total	28707	13347	890	444

Potential habitat was taken and modified from Zarza *et al*. (this volume), and refers to forest vegetation. *Population size refers to the number of individuals based on 6.67 and 3.33/100 km^2.

and productive activities. Certain conservation mechanisms that are complementary to protected areas have already been implemented in different regions of the Yucatan Peninsula and should be applied to other areas to increase the surface of protected forest. For example, Amigos de Calakmul A.C. has signed agreements with several ejidos in the southern part of the buffer area of Calakmul Biosphere Reserve whereby more than 200 families of common land owners receive payment for maintaining their forests (G. Ceballos, pers. obs.). Another example is that of forest ejidos such as Caoba, where forest exploitation has made it possible to maintain their forests and wildlife.

It is clearly still possible to conserve most of the remnant forests in the Yucatan Peninsula. However, the threats are severe and there is little time left to take action. The presence of jaguars in the Maya Forest of southeastern Mexico, northern Guatemala and Belize is an encouraging sign. However, it requires conservation actions at different levels, from local to State and National governments. As scientists, our role is to provide the scientific basis to achieve this goal and give social relevance to our work.

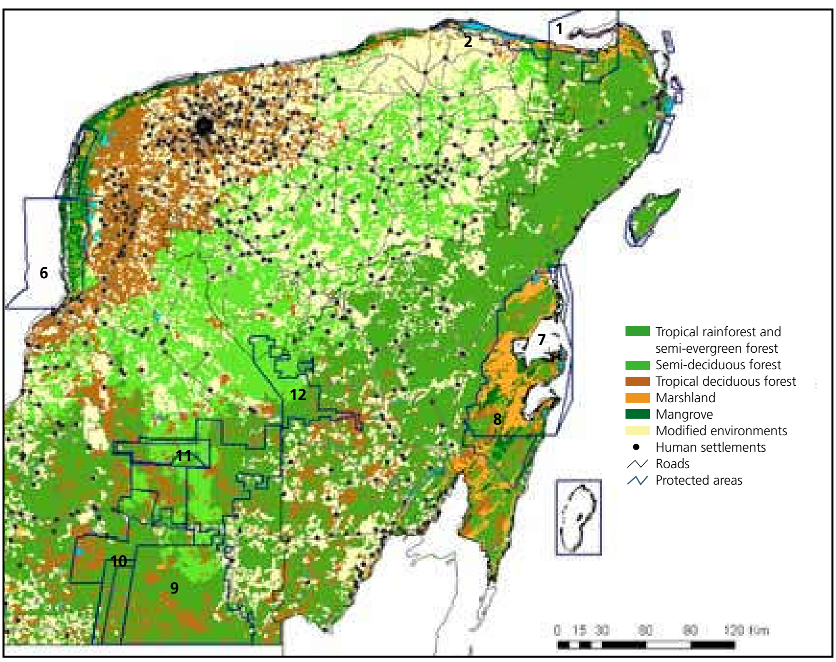


Figure 6. Protected areas and vegetation types in the Maya Forest, Yucatan Peninsula, according to the National Forest Inventory (Semarnat *et al.*, 2001). Names of protected areas are shown in Table 1.

Acknowledgments

We wish to thank the various institutions and people that have contributed to the success of the project for their support: Unidos para la Conservación, Sierra Madre, National US Fish and Wildlife Foundation, Fondo Mexicano para la Conservación de la Naturaleza, Safari Club International, the Dirección General de Asuntos del Personal Académico (DGAPA) of UNAM, through its project IN-246602, Consejo Nacional de Ciencia y Teconología (Conacyt) through project 34855-V; Semarnat-Conacyt 1424 for funding and logistical support; the authorities of the Secretaría del Medio Ambiente y Recursos Naturales (Semarnat, INE, Profepa), and the management of the reserve for providing permits to work with jaguars and helping us supervise the project. At different stages of the project, support and advice were provided by our colleagues Carlos Manterola, Antonio Rivera, Francisco Zavala, Patricio Robles-Gil, Felipe Ramírez, Ignacio March and Gerardo García Gil. We also wish to thank Ejido Caoba for allowing us to work on its land, and Unidos para la Conservación, Ecosafaris and the Universidad Nacional Autónoma de México (UNAM) for their permanent support.

JAGUAR HABITAT USE IN A HUMAN DOMINATED LANDSCAPE IN THE YUCATAN PENINSULA, MEXICO

Heliot Zarza, Cuauhtémoc Chávez, and Gerardo Ceballos

Resumen

El acelerado crecimiento de las actividades humanas, ha modificado grandes extensiones de bosque tropical, fragmentándolas y reduciendo el hábitat disponible para la fauna silvestre. Las poblaciones de jaguar han disminuido a lo largo de su distribución debido principalmente a la pérdida del hábitat. La Selva Maya en la Península de Yucatán mantiene la población más numerosa de jaguar en México. La conservación de la especie en esta región requiere del manejo adecuado de su hábitat. El objetivo de este trabajo es determinar los requerimientos de uso de hábitat y los efectos de la perturbación humana (poblados y caminos) sobre el jaguar en la Selva Maya del sur de la Península de Yucatán. Para determinar las preferencias en el uso del hábitat, se analizaron los movimientos de jaguares por tipos de vegetación, uso de suelo, distancia a poblados y caminos en un Sistema de Información Geográfica. Los datos se obtuvieron a partir del seguimiento de jaguares con collares de GPS. Nuestros resultados revelan que los jaguares prefieren marcadamente los ambientes forestales (i.e. selva alta y mediana) en comparación con otros tipos de vegetación con menor cobertura forestal. Usan con mayor frecuencia, las áreas alejadas a más de 6.5 km de los poblados y 4.5 km de las carreteras. Las Áreas Naturales Protegidas (ANP) de la región, mantienen más del 68% de su superficie como hábitat para el jaguar. Fuera de las ANP, hay grandes extensiones de hábitat de jaguar, que pueden ser usadas como corredores biológicos, para mantener la conectividad, los procesos ecológicos, y el potencial de la región para la conservación a largo plazo del jaguar y de la biodiversidad.

Palabras clave: jaguar, requerimientos de hábitat, corredores para fauna, reservas, Selva Maya, Calakmul, Península de Yucatán.

Abstract

Habitat encroachment by human activities has extensively modified large extensions of tropical rainforest, reducing wildlife habitat availability. Jaguar populations have been steadily declining due to changes in land use and poaching. The largest jaguar population in Mexico is found in the Selva Maya region, in the Yucatan Peninsula. Conservation of jaguar in the Selva Maya requires a careful management of its habitat. So, the aim of this study was to determine jaguar habitat requirements and the effects of human perturbation (e.g. roads and towns) on habitat use. Habitat preferences were analyzed using data on *jaguar movements across habitat types, land use, distance to human settlements and roads using a GIS. Data on jaguar movements were obtained with GPS radio-collars. Results indicate that jaguars extensively use forested habitats such as tropical semi green forests. They use more frequently than expected by chance areas located more that 6.5 km from human settlements and 4.5. km from roads. Around 68% of the land in the regional protected areas is the preferred jaguar habitat. Outside protected areas there are still extensive areas with jaguar preferred habitat; those areas are essential to maintain connectivity among reserves, environmental processes, and the long term conservation of jaguars and many other species.*

Keywords: jaguar, habitat requirements, wildlife corridors, reserves, Selva Maya, Calakmul, Yucatan Peninsula.

Introduction

The fast growth of human population has caused severe changes in the dynamics and ecological processes of tropical rainforests in the world (Baillie *et al.*, 2004; Geist and Lambin, 2002). In these regions, programs aimed at developing agriculture and forest exploitation have been promoted to satisfy the demands of the human population (FAO, 1999). This has led to a fast change in land use. Tropical rainforests are transformed into an irregular matrix where human activities dominate the new landscape and have a direct impact on regional biodiversity. This is reflected in an increase in the mortality rate of some species and the disruption of ecological processes (Dirzo and Raven, 2003; Fahrig, 2003; Kinnaird *et al.*, 2003; Reed, 2004). Environmental degradation has increased conflicts between humans and large carnivores, mainly due to habitat loss, a decline in natural prey caused by overhunting, and poor livestock management (Hoogesteijn *et al.*, 2002; Lynam *et al.*, 2006; Sáenz and Carrillo, 2002; Treves and Karanth, 2003).

The creation of protected areas has globally been promoted as a general strategy to reverse the negative effects of habitat loss and fragmentation in carnivore populations and biodiversity in general (Bruner *et al.*, 2001; IUCN, 2006). Unfortunately, protected areas themselves are usually insufficient to maintain viable populations of large carnivores in the long term, due to the large home ranges of carnivores and their ecological requirements in terms of habitat and prey (Noss *et al.*, 1996; Ramakrishnam *et al.*, 1999; Shivik, 2006; Woodroffe and Ginsberg, 1998). In recent years, complementary conservation strategies to protected areas have been proposed with the aim of better managing areas adjacent to protected areas (e.g., Daily *et al.*, 2003).

Jaguars (*Panthera onca*) are one of the species whose distribution and abundance has been modified as a consequence of habitat loss, forest conversion to agriculture and poaching (Ceballos *et al.*, 2006; Nowell and Jackson, 1996). A considerable percentage of the jaguar's historical range has been lost (Sanderson *et al.*, 2002c). In Mesoamerica, the Maya Forest region in Mexico, Guatemala and Belize contains viable jaguar populations (Chávez and Ceballos, 2006; Sanderson *et al.*, 2002a, c). Despite the major environmental change caused by intense human colonization in the area, there are still large stretches of well-preserved forest in communal lands, known as ejidos (Boege, 1995; Chowdhury, 2006; Turner II *et al.*, 2001).

The southern Yucatan Peninsula includes several protected areas, the largest of which are Calakmul and Sian Ka'an Biosphere Reserves; however, if deforestation trends in the region are not reverted in the short term, both protected areas and forest areas (e.g., forest ejidos) will become islands unable to maintain jaguar populations and regional diversity (Ceballos *et al.*, 2005). If jaguar conservation is to be successful, human-dominated areas will have to be included in regional and national conservation strategies. To do so, it is necessary to identify priority areas for jaguar conservation (Hatten *et al.*, 2005; Wikramanayake *et al.*, 2004). The objective of this study was to determine jaguars' habitat use and requirements jaguars in an area dominated by human activities and develop a habitat prediction model for the species in southern Yucatan Peninsula to design a regional jaguar conservation strategy. This study complements that of Zarza *et al.* (2005).

Study area and methods

This study was conducted south of the states of Campeche and Quintana Roo, Mexico, at two spatial scales. The first scale was a focal study area of about 1,100 km^2 in Ejido Caoba (18º 14' N, 89º 03' W; Figure 1). The dominant vegetation in the region is tropical rainforest and semi-evergreen forest, and –to a lesser extent– tropical deciduous forest and seasonally flooded forest (Semarnat *et al.*, 2001). The main economic activities in the ejido are forest exploitation and crop and livestock farming. Although hunting is not permitted in the forest exploitation area, it is common practice. The ejido is home to 1,322 people, who live in two villages (INEGI, 2005).

The focal study area is located in a region of approximately 78,000 km^2, between parallels 19° 30' and 17° 50' N and meridians 90° 25' and 87° 30' W (Figure 1). The second level of the study involved modeling potential jaguar habitat at a regional scale. Although the boundaries of the region do not represent ecological or political boundaries, we decided to cover the area delimited by Calakmul Biosphere Reserve in the west and Sian Ka'an Biosphere Reserve in the east, including both reserves. This region has the largest remaining area of Mexican tropical forest (Martínez and Galindo-Leal, 2002). It is basically flat, with an elevation ranging from 100 to 300 masl, and has sub-humid tropical climate, with a mean annual temperature of 24.6 °C and considerable seasonal changes. The wet season lasts from June to November, and mean annual rainfall is 1,076 mm (Turner II *et al.*, 2001). About one third of the region is flooded during the wet season. There are virtually no permanent rivers or streams in the Calakmul region (Semarnat, 2000).

Capture and telemetry

Jaguars were captured in the dry season –February to May– from 2001 to 2003 (for more details on capture methods, see Ceballos *et al.*, 2002; Chávez, 2006; Chávez *et al.*, this volume).

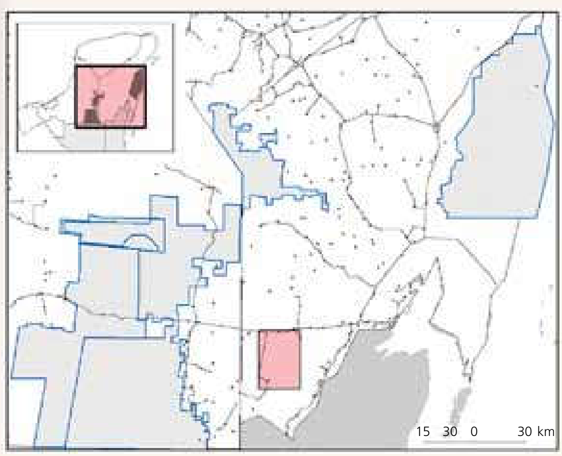
Individuals captured were fitted with a GPS collar (Televilt, CA); their movements were monitored flying over the study area with a light aircraft. Data were directly downloaded from the collars of jaguars recaptured the following year.

Landscape variables

To determine habitat use preferences of the jaguar in the region, we analyzed three variables of the landscape on a regional scale-vegetation type and land use, human settlements and roads. Vegetation type and land use were obtained from the 2000-2001 National Forest Inventory at 1:250,000 scale (Semarnat *et al.*, 2001). We clustered the 23 vegetation classes of the inventory into 10: tropical rainforest and semi-evergreen forest, tropical deciduous forest, seasonally flooded forest, secondary vegetation, other habitats, agriculture, grassland, urban areas and bodies of water. Vegetation types present in less than 2% of the study area were included in "other habitats." This classification is based on the one made for the Calakmul region by Martínez and Galindo-Leal (2002).

Data on roads and human settlements were obtained from INEGI (Mexican National Institute of Statistics and Geography) and Conabio (Mexican National Com-

Figure 1. Study area in southern Campeche and Quintana Roo, Mexico.



mission for the Knowledge and Use of Biodiversity) in vector format at 1:250,000 scale. We only considered paved roads connecting settlements with a population of over 200 people because updated information is not available and several settlements have been abandoned in the last few years. We ruled out dirt roads, trails and paths because they are used by jaguars and do not limit their movements (C. Chávez, pers. obs.) The region is basically flat, so it was not possible to include thematic variables such as elevation and slope in the model. Hydrologic variables were not used because the region has no permanent rivers.

Habitat use

To determine habitat use, we used 620 records or locations of four female jaguars. The error of the records was estimated at 15 m, and we eliminated duplicated records. To avoid self-correlation between the data, we only considered data with a one-day interval at least (Núñez *et al.*, 2002). We randomly selected 50% of the records (n = 310) as modeling points and used them to develop the model and analyze habitat use. The remaining records were used to validate the model and were called "validation points." We used the "modeling points" to analyze the proportion of points observed and expected for each vegetation type and land use, as well as proximity to human settlements and roads using a Geographic Information System (ArcGIS 8.3, Environmental Systems Research Institute, Redlands, California, USA).

All the vegetation types in the focal study area were defined as available habitat. Vegetation types and land uses were classified according to the occurrence of jaguar records relative to that expected by chance. Habitats with a lower occurrence of records than would be expected by chance were defined as low-use habitat, those with an occurrence similar to their availability in the study area were defined as used habitat, and those with an occurrence greater than would be expected based on their availability in the study area were defined as high-use habitat. We used the X^2 goodness-of-fit test to determine whether jaguars used habitats according to their availability in the study area (Byers *et al.*, 1984; Neu *et al.*, 1974). We used Bonferroni Z confidence intervals to determine whether the category(-ies) or distance(-s) were significantly used more or less relative to their availability (Byers *et al.*, 1984). All the statistical analyses and tests were determined with a $P < 0.05$.

We identified the different habitat types –low-use, used, and high-use– for each variable based on the jaguars' habitat use preferences. After this, we overlaid the different ArcView 3.2. layers (ESRI, 1999) and obtained a map, which was used to validate the model with the validation points. Finally, we generated a predictive map of potential jaguar habitat by extrapolating the parameters used in Ejido Caoba to southern Campeche and Quintana Roo.

Results and discussion

Habitat use

The habitat available in the study area is formed by a matrix of vegetation types and land uses. The dominant vegetation is tropical and semi-evergreen forest (46%), followed by secondary vegetation (22%), grassland (14%), and finally seasonally flooded forest (11%). Jaguars showed marked preferences in habitat use between forest and modified areas. Although jaguar is a large, generalist and highly mobile species that are able to occupy several habitat types in the landscape matrix, it clearly shows habitat preferences. Jaguars used forest habitats more than expected (n = 239; 77%), compared to habitats modified by human activities ($X^2 = 38.3$, $P < 0.05$, Table 1).

The analysis of habitat preferences according to vegetation types and land use showed significant differences between available habitat and the various vegetation types considered ($X^2 = 82.1$, $P < 0.05$). Tropical rainforest and semi-evergreen forest were high-use habitats (58%) and occurred in more records than expected according to their availability (Table 1). Seasonally flooded forest and secondary vegetation were used proportionately to their availability. Cropland and urban areas were low-use habitat (Table 1). Similar results have been observed for other large carnivores such as tigers, pumas, bears and wolves; forest habitats are the best predictors of available habitat for these species (Koehler and Pierce, 2003; Lyons *et al.*, 2003; Miquelle *et al.*, 1999; Mladenoff *et al.*, 1995; Riley and Malecki, 2001).

Human settlements have a major impact on the spatial distribution of jaguar (Table 2). The highest occurrence of jaguars (> 80% of records) was found at a distance > 6.5 km from human settlements ($X^2 = 75.9$, $P < 0.05$). Jaguars also avoided

Table 1. Jaguar habitat selection according to vegetation type and land use in the southern part of the Yucatan Peninsula, Mexico

Landscape variable	Records % (n = 310)	Bonferroni confidence intervals
Natural habitats	77.1	S
Modified habitats	22.9	A
X^2= 38.3, gl = 1, $P < 0.05$		
Vegetation types and land use		
Tropical rainforest and semi-evergreen forest	58.7	S
Seasonally flooded forest	18.4	P
Other habitats	0.0	A
Secondary vegetation	21.6	P
Grassland	1.3	A
Cropland	0.0	A
Urban areas	0.0	A
X^2= 87.1, gl = 6, $P < 0.05$		

Bonferroni confidence intervals show: A = avoided, P = proportion and S = selected areas < 1 km from settlements. Studies on other carnivores have shown a similar pattern, that of avoiding or reducing use of areas near human settlements (Kerley *et al.*, 2002; Koehler and Pierce, 2003; Mladenoff and Sickley, 1998). The landscape around human settlements (< 6.5 km) is dominated by cropland, grassland, roads, small patches of mature forest and secondary vegetation. In the region, local people practice traditional or subsistence hunting within a minimum radius of 6 km from their settlements (Escamilla *et al.*, 2000; Jorgenson, 1995). There is considerable overlap between the jaguar's main prey –Central American agouti (*Dasyprocta punctata*), peccary (*Tayassu tajacu*) and armadillo (*Dasypus novemcinctus*)– and the prey hunters are interested in (Amín, 2004; Chávez *et al.*, this volume). Added to habitat fragmentation and modification, this leads to a decrease in the number of prey available for jaguars and a possible increase in interactions with people. The paved road was found to have a lower impact than human settlements on the spatial diestibution of the jaguar. The highest occurrence of jaguars (> 80% of records) was found at a distance > 4.5 km from the road ($X^2 = 209.5$, $P < 0.05$). Areas with the lowest occurrence (< 4%) were those located at a distance < 1.5 km from the road. These results partially support the hypothesis of the direct effect of roads on mortality of carnivores and their prey (Kerley *et al.*, 2002; Mladenoff and Sickley, 1998; Noss

Table 2. Effect of the road and human settlements on jaguar's habitat selection in the southern part of the Yucatan Peninusla, Mexico

	Bonferroni confidence intervals			
Distance (m)	**Road[1]**		**Settlements[2]**	
500	0.6	A	0.0	A
1000	1.3	A	0.0	A
1500	1.9	A	0.3	P
2000	2.9	P	0.0	A
2500	1.3	A	0.6	A
3000	1.9	A	0.3	A
3500	3.5	P	1.9	P
4000	2.9	P	2.6	P
4500	5.2	P	1.6	A
5000	5.2	P	3.9	P
5500	4.5	P	2.9	P
6000	5.8	P	2.9	P
6500	6.5	P	5.2	P
7000	5.2	P	4.5	P
7500	8.7	S	11.0	S
8000	13.5	S	11.6	S
8500	9.7	S	8.1	P
>9000	19.4	S	42.6	S

[1] X^2= 201.6, gl = 16, $P < 0.05$

[2] X^2= 51.8, gl = 16, $P < 0.05$

Bonferroni Z confidence intervals show: A = avoided, P = proportion and S = selected *et al.*, 1996). Although the three landscape variables analyzed are related to each other, vegetation type was found to have the greatest weight. Human settlements and roads showed an effect on the jaguar's spatial distribution; the effect of each of these variables was found to be independent and in some cases synergistic.

Habitat model

We developed a model based on the jaguar's habitat use preferences. High-use habitat has a high probability of occurrence (0.6-1) and includes areas with tropical rainforest and semi-evergreen forest located > 6.5 km from human settlements and > 4.5 km from roads. Used habitat has a medium probability of occurrence (0.2-0.6) and includes vegetation types and land uses that jaguars use depending on their availability, located 2-6.6 km from human settlements and 1-4.5 km from roads. Low-use habitat has the lowest probability of occurrence (0-0.2) and includes the vegetation types and land uses avoided by jaguars, < 2 km from human settlements and 1 km from the road.

The habitat model identified most of the study area as used habitat and high-use habitat for jaguars. There are large areas of these types of habitat in the south, center and east of the study area (Figure 2). Based on probabilities of occurrence, the area including high-use habitat was estimated to cover 35,849 km^2 (45.8%), used habitat was estimated to cover 23,076 km^2 (9.4%), and low-use habitat was estimated to cover 19,387 km^2 (24.8%). The verification of the model showed that 96.5% of jaguars points were located in high-use habitat (56.8%, n = 176) and used habitat (39.4%, n = 123). The same trend was observed in the validation stage; 96% of jaguar records came from the area classified as high-use habitat (57%, n = 177) and used

Table 3. Land area and percentage of habitat used by jaguars in the protected areas in the study area in the aouthern Yucatan Peninsula, Mexico

Protected Area	Surface (ha)	Predicted probability of occurrence ha (%)		
		Low	Medium	High
Calakmul Biosphere Reserve	723,185	4,906	158,385	447,830
		(1.6)	(25.8)	(72.5)
Sian Ka'an Biosphere Reserve	528,147	74,900	163,935	105,668
		(21.5)	(47.6)	(30.8)
Balam Kú Biological Reserve	409,200	3,521	106,513	235,290
		(1.0)	(30.8)	(68.1)
Balam Kin Biological Reserve	110,990	285	15,285	84,036
		(0.3)	(15.3)	(84.4)
Bala'an Ka'ax Flora and Fauna Protection Area	128,390	1,570	24,500	99,540
		(1.3)	(19.5)	(79.2)

habitat (39%, n = 121), as predicted by the model. This means that the model is consistent and highly reliable in predicting potential jaguar habitat in the Maya Forests of southern Campeche and Quintana Roo, Mexico.

About 68% of the surface of the protected areas in the study area (Table 3) is estimated to be high-use habitat, with the exception of Sian Ka'an Biosphere Reserve, which only has 30% of high-use habitat. Although nature reserves are protecting part of the habitat necessary to maintain jaguars in the region, these areas are probably insufficient to guarantee the long-term survival of the species. It is therefore necessary to develop a conservation strategy that considers the forest areas outside protected areas that fulfill the necessary ecological conditions for the survival of the jaguar and regional biodiversity (Daily *et al.*, 2003). Determining habitat use requirements in areas influenced by human activities makes it possible to understand habitat use preferences, analyze how jaguars perceive these new changes and determine where management and conservation efforts should be targeted (Hatten *et al.*, 2005; Ortega-Huerta and Medley, 1999).

In Mexico, any jaguar conservation strategy must be approached from a regional scale, taking protected areas as cornerstones. However, adjacent areas must also be included. This requires solid strategies that take into account the species' biological requirements and main threats as well as the social reality of the region. This can be done by promoting sustainable projects such as ecotourism or apiculture to improve the social welfare of local people by giving an added value to natural resources.

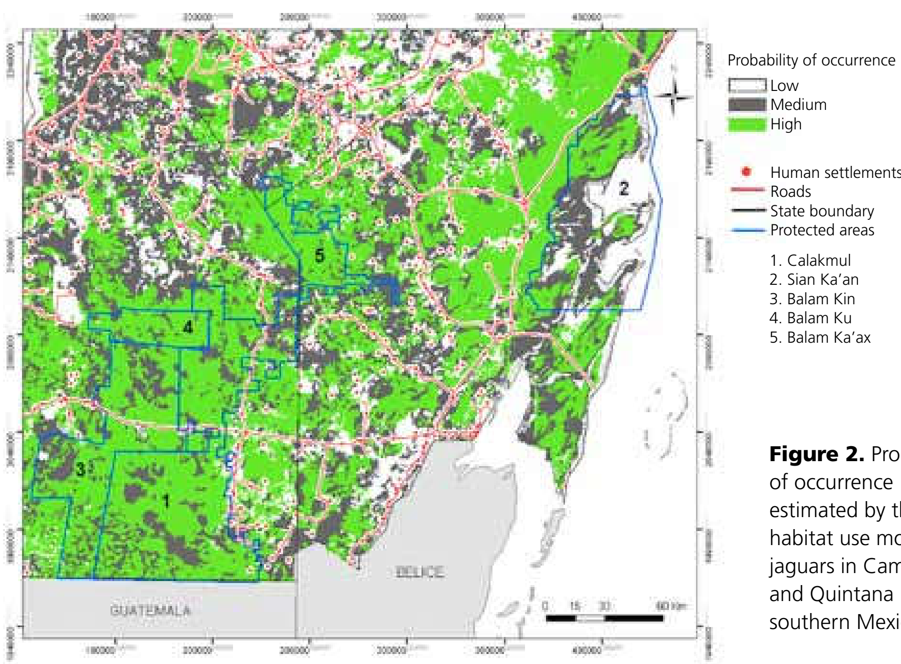


Figure 2. Probability of occurrence estimated by the habitat use model for jaguars in Campeche and Quintana Roo, southern Mexico.

Recommendations

Local and regional development programs must include ecological and biological criteria to make decisions on future projects. Considering the effect of the biological, social and economic interests of the region will lead to better decision making. Including the communities living around the protected areas in the region will lead to better conservation prospects inside the reserves, thus minimizing possible agonistic interactions between large species and humans.

Acknowledgments

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JAGUAR POPULATION DENSITY AND SIZE IN THE NORTHEASTERN YUCATAN PENINSULA

Juan Carlos Faller, Cuauhtémoc Chávez,
Stacey Johnson, and Gerardo Ceballos

Resumen
El norte de la Península de Yucatán es una de las áreas prioritarias en México para la evaluación de la situación actual del jaguar. Las únicas investigaciones sobre la ecología y la conservación del jaguar en la península se han realizado 400 km al sur de esta provincia biótica, en las selvas más húmedas de Campeche y Belice. Del 2004 al 2006 se llevó a cabo un estudio con trampas-cámara en los humedales costeros de Ría Lagartos, en el noreste de Yucatán, con objeto de evaluar su situación actual, densidad y tamaño poblacional. Las densidades obtenidas fluctuaron entre dos y seis jaguares por cada 100 km^2. Se documentó en la región existen cerca de 4,000 km^2 de hábitat potencial para el jaguar. La población probable varía entre 80 y 240 jaguares. Es decir, la región mantiene una de las poblaciones más importantes del jaguar en México, por lo que es prioritaria para la conservación de la especie. Sin embargo, la región afronta actualmente serios problemas de conectividad con las otras porciones de las selvas mayas del sur principalmente debido a la infraestructura carretera. Las selvas hacia el oriente son ya prácticamente inexistentes por el avance de las fronteras agrícola y ganadera. Por ello, se requiere de una estrategia sólida de conservación para evitar la extinción del jaguar en la región a largo plazo.

Palabras clave: humedales costeros, jaguar, densidad de población, Península de Yucatán, Ría Lagartos, Yum Balam.

Abstract
The northern region of the Yucatan Peninsula is a priority area in Mexico for the evaluation of jaguar's conservation status. The only studies on the ecology and conservation of jaguar in the peninsula have been carried out 400 km south, in Campeche and Belize. This study was carried out with camera-traps in the costal wetlands and tropical dry forest of Ria Lagartos, in the northeastern part of the peninsula from 2004 to 2006. Population densities varied from 2 to 6 jaguars per 100 km^2. We also document that there are around 4 000 km^2 of jaguar habitat in the region. So, the jaguar population size probably varies from 80 to 240. Indeed, this is one of the most important jaguar populations in Mexico, so it is should be considered a priority for conservation. The region has, however, severe environmental problems, and its connectivity with other forests to the south is already impacted by highways: in addition, the forests to the west are practically nonexistent due

to the expansión of agriculture and cattle ranching. That's why a solid strategy is needed in order to maintain this jaguar population in the long term.

Keywords: Coastal wetlands, jaguar, tropical dry forests, jaguar, Yucatan Peninsula, Ría Lagartos, Yum Balam.

Introduction

Progressive habitat destruction, poaching, diseases and other factors such as road building have caused a gradual decrease in the range of the jaguar (*Panthera onca*) in Mexico and other countries (Medellín *et al.*, 2002; Swan and Teer, 1989). The probability of conserving the species in the long term greatly depends on maintaining the highest number of populations, which should contain the highest number of individuals (Carrillo *et al.*, this volume). An essential strategy for jaguar conservation is therefore to identify priority conservation areas (Ceballos *et al.*, 2006; Sanderson *et al.*, 2002a, b). Conservation of such areas should be given priority by promoting the different possibilities –from the creation of protected areas to payments for ecosystem services– as well as the conservation of the jaguar, its habitat and its prey.

Although the current distribution of jaguars is relatively well known, the status of its populations is unknown in broad regions (e.g., Chávez and Ceballos, 2006; Núñez, this volume). Persistence of jaguars on a local and regional level not only has major ecological implications because of its role in natural communities, but also has social implications, given its cultural importance and its conflicts with livestock farmers.

Recent studies have identified priority regions for jaguar conservation in Mexico (Ceballos *et al.*, 2006; Sanderson *et al.*, 2002c). The largest jaguar population occurs in the south of the Yucatan Peninsula, in the Calakmul region in Campeche and Quintana Roo (Ceballos *et al.*, 2002; Chávez *et al.*, this volume). This population has a high probability of long-term survival, especially if the biological reserves established in the Calakmul region are consolidated and the regional environmental threats such as deforestation and road building are mitigated over the next decades (Conde *et al.*, 2006; Chowdhury, 2007; Vester *et al.*, 2007; Zarza *et al.*, this volume).

The status of jaguars is unknown in other regions of the Yucatan Peninsula. Although the species is present, there is little information about population density and size (Navarro-Serment *et al.*, this volume). The north of the peninsula still has vast stretches of well-preserved habitat, but jaguar's current status is unknown. Hence, the region has been considered a high-priority area to assess the jaguar's current status (Ceballos *et al.*, 2006; Sanderson *et al.*, 2002c). This study provides an analysis of jaguar population density and size in the region of Ría Lagartos. The objective of the study was to determine whether a jaguar population exists in the region and, if so, whether it is likely to survive in the long term.

Study area

The study area is located in the eastern and southeastern parts of the Ría Lagartos Biosphere Reserve and its area of influence. The region is located in the northeastern Yucatan Peninsula, between longitudes 87°30' and 87°40' West and latitudes 21°15' and 21°30' North (Figure 1). About 40% of its surface falls within the biosphere reserve. The rest is in its southeastern area of influence, which includes "El Zapotal" private reserve (23.5 km^2) and land of neighboring ejidos (Faller, 2010b). The biosphere reserve is part of a wetland system that includes two other coastal reserves, Yum Balam Flora and Fauna Protection Area and Bocas de Dzilam State Reserve. Altogether, these protected areas contain about 1400 km^2 of forests and wetlands (PPY, 2005).

The topography of the region is flat or almost flat, with slight slopes. It is part of a limestone platform with no surface streams or rivers. Water filters down, forming a shallow water table formed by caves, underground rivers, sinkholes called cenotes –permanent freshwater bodies– and aguadas –temporary freshwater bodies– (INE, 1999). Although the area is considered as being in the sub-humid tropics, it is in fact in the transition between the sub-humid and humid tropics. This is why some typical animal and plant species of both ecosystems can be found in this region (Challenger, 1998). More than half (68%) of the study area is covered by semi-evergreen forest over 20 years old; about 7% is devoted to crop and livestock farming, and the rest is a combination of seasonally flooded forest (4%), natural savanna (4%), second-

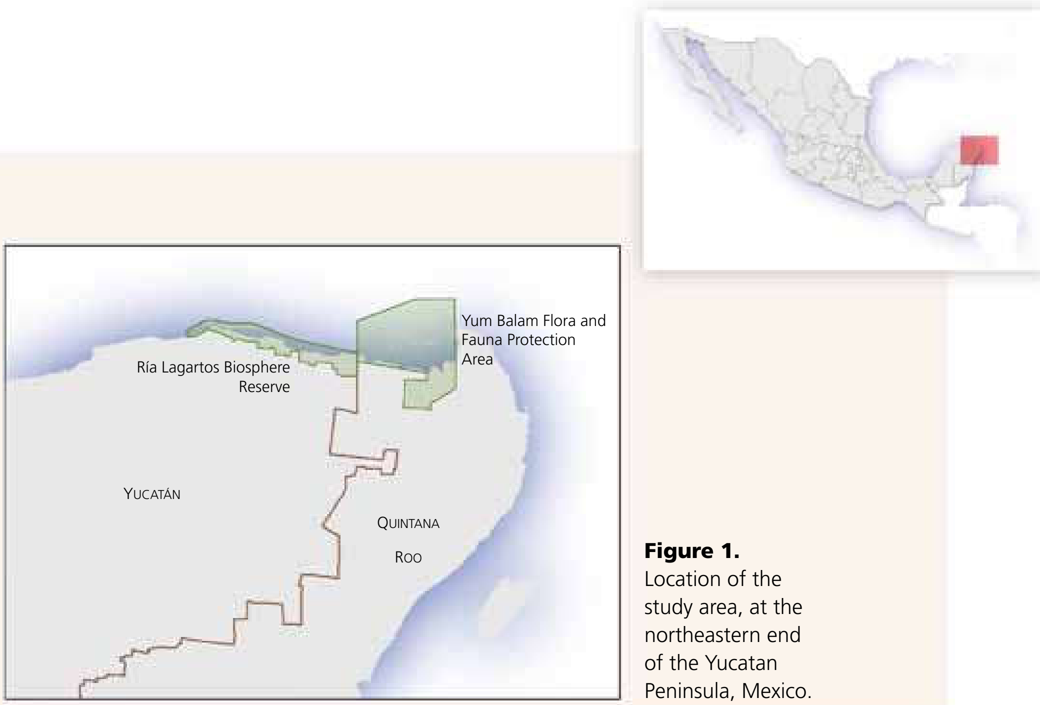


Figure 1. Location of the study area, at the northeastern end of the Yucatan Peninsula, Mexico.

ary vegetation over 15 years old (7%), and part of a system of marshes, mangroves and petenes –emerging islands of forests protected from saline intrusions– (García-Contreras and Vera, 2004).

Average rainfall ranges from 700 mm in the north to 1,100 mm in the south (García-Contreras and Vera, 2004). The rains fall in two distinct seasons; from June to November (70% of total annual rainfall) and from December to May (30% of total rainfall). Monthly mean temperature is around 26°C, with a temperature range of 3°C (INE, 1999). Winds are moderate from November to August, but September and October are considered to be the hurricane season, with winds exceeding 120 km/h. The region has been struck by 9 tropical hurricanes between 1957 and 1996, which amounts to one every 4.3 years on average (INE, 1999).

The study area includes the village of Tesoco Nuevo, with a population of about 300 people, and five small settlements with 30 to 40 people (INEGI, 2000; Urquiza and Ku, 2004). Until about a hundred years ago, the entire north east of the peninsula was practically uninhabited (Reed, 1971), and mainly covered by semi-evergreen forest in a late successional stage (PPY, 2005). Industrial logging began in the 1930s (F. Faller, pers. comm.), and livestock farming started to expand in the 1950s, and grew significantly between 1970 and 1990 (Fraga and Cervera, 2003).

Methods

To assess jaguar presence and density, we used 18 to 27 camera trap stations per year. Camera traps have become an important tool to monitor rare and cryptic terrestrial species in tropical forests (Azuara and Medellín, this volume; Wallace *et al.*, 2003). The unique spot patterns on the coats of jaguars were used to estimate population size with capture-mark-recapture models (Silver *et al.*, 2004). All the cameras were DeerCam® DC-200 except one, which was Camtrakker®. Both models are passive traps, triggered by an animal passing in front of sensors that detect heat and movement (Lynam, 2002). The camera traps were placed in an area of 100 km^2, using stratified random sampling with certain discrimination criteria. A recent (2003) georeferenced satellite image with a resolution of 2 meters was divided into 1 km^2 plots with Arcview® software. This surface represents about 10% of a jaguar's minimum home range in one season, based on data obtained in a region relatively near the study area (Ceballos *et al.*, 2002; Lynam, 2002). The plots were clustered into four groups of 23 to 27 units called sections.

To be selected, the 1 km^2 sampling plots had to meet the following conditions: very open vegetation (grassland, savannas or vegetation in successional stages less than 10 years old) must not cover more than 50% of their surface; they should not have trails regularly used by local people or cultivated plots, because the risk of camera theft increases considerably in these circumstances; the sites had to be accessible, with boundaries not too far (less than 1.5 km) from tracks and trails known or identifiable on the satellite image. All the plots were randomly selected.

In the first fieldwork season of 2004 –from February to July– we selected six plots in sections 1, 2 and 3. We only chose three plots in section 4. In each plot, we placed a camera trap at three or four of the vertices of an inner concentric 330 meter-long side square, called camera trap station. To choose the sites where cameras would be placed, we took into account factors such as the presence of tracks, trails used by wildlife, and the location of water bodies, to maximize the chances of obtaining pictures. The cameras were programmed to be active 24 hours a day. Each section was used for a 4-6 week period. Some camera trap stations were only fitted with three cameras because of technical problems in some cameras.

The second stage of fieldwork in 2004 was aimed at obtaining information to complement the data obtained in the previous stage. It involved installing 10 cameras in different sites of Section 1 that had not been covered in the first stage, mainly paths where felid tracks and other signs are often found. Section 1 is located in "El Zapotal" private reserve.

The design was modified in 2005. We used Arcview® to outline a hexagonal grid with a side length of 3 km on the georeferenced satellite image, and used this grid to install the camera traps. We followed the method suggested by Sanderson (2003), taking into account the minimum home range estimated for the jaguar in the peninsula (Ceballos *et al.*, 2002; Lynam, 2002). In developing the grid, an effort was made to ensure that the vertices and centers of the polygons matched places jaguars were most likely to visit. We selected 15 sites to install camera trap stations. Each station consisted of two camera traps facing each other. The cameras were activated in the second week of May and remained active until July.

In 2006, because of limitations by the passing of two hurricanes, the network of camera trap stations with two cameras per station only covered 8 sites, with distances ranging from 0.9 to 1.6 km between stations. The sites were selected on the basis of data obtained in the two seasons, to maximize capture probability. The camera trapping network was active from May to July.

Data analysis

To interpret the results of the 2004 season, we defined the center of the 1 km^2 plots where the three or four cameras of each station were installed as the "effective camera trapping center." Sampling effort was the number of days that each camera station was in operation. For each of the sampled years, our capture period was 24 hours, regardless of the time lag of one or two days between each of the sampling stations. We define "capture ocasion" as the event of obtaining photographs of the same individual within a period of 24 hours inside the whole web of sampling stations. In this sense, each "capture" or "recapture" stands for the set of images contained in a capture occasion. To estimate population density, we built the capture-recapture histories of jaguars for each of the three years sampled (2004, 2005 and 2006). Data obtained were fed into matrices of zeros (absence) and ones (presence), where each column represents one day of capture effort and each row represents one jaguar. This data arrangement was chosen in order to process the data with the CAPTURE program and obtain an estimate of jaguar population size (Otis *et al.*, 1978; Rexstad and Burnham, 1991). For 2004, we only used the capture-recapture information obtained in Stage 1, using the method followed by Karanth and Nichols (2002) and Silver *et al* (2004).

To estimate the size of the effective sampling area for each year, we calculated the mean maximum distance moved (MMDM) by individual jaguars between cameras for three years, and used half of this distance (½ MMDM) as a radius to trace a circle around the location of each camera trap (Dice 1988; Wilson and Anderson, 1985). The polygon formed by overlaying these circles formed the total sampling area of the camera trap network. The total surface of this effective sampling area was calculated using ArcView® X-Tools and Spatial Analyst. The number of jaguars captured every year was divided by the surface of the effective sampling area to calculate jaguar density. This assessment method has been comprehensively described in other publications (Di Bitetti *et al.*, 2006; Karanth, 1995; Karanth and Nichols, 1998; Nelly, 2003; Maffei *et al.*, 2004; 2005; Silver *et al.*, 2004). Density estimates are the result of combining estimated population size and effective sampling areas. We calculated standard errors in density estimates following Nichols and Karanth (2002).

Results and discussion

According to the results, there is a relative large jaguar population in the study area. We obtained 45 "capture occasions" of 8 individuals in three years of sampling (Table 1; Figures 2, 3). Maximum distances traveled in one year ranged from 1.0 to 10.2 km, with a mean of 4.8 km and a standard deviation of 1.8 km (Figures 4, 5, 6).

The "constant capture probabilities model", M (o) and the "constant capture probabilities model", M (h) of the CAPTURE program were the most appropriate to assess jaguar density in the study area, as they were the best fit models. We used the variable capture probability model for 2004 and 2005, and model M (o) for 2006 data as a more conservative estimate, because there were major inconsistencies in the runs made with model M (h) (Table 2).

Estimated densities were very variable and ranged from 1.82 to 6.18 individuals/100 km^2. The variation in estimation density is probably due to factors related to the sampling methods and natural factors. For example, although there was little variation in the effective sampling area between 2004 and 2005, there was a considerable difference in sampling effort (Table 2). On the other hand, there was little variation in the temporal sampling effort between 2005 and 2006, but a significant difference in the effective sampling area. The density obtained in 2006 (6.18 ind./100 km^2) is probably the result of using a very small effective sampling area, which could fail to accomplish the closed population assumption (L. Maffei, pers. comm.). Thus, the model could not adjust to a closed population. It is also important to note that

Table 1. Capture of jaguars with camera traps in Ría Lagartos, Quintana Roo, between 2004 and 2006

Individual	Year 2004	Year 2005	Year 2006	Total
1. Francisco	8	2	0	10
2. Joann	1	0	0	1
3. Jaguar 2	2	0	5	7
4. Jaguar 3	2	4	0	6
5. Jaguar 4	1	0	0	1
6. Jaguar X	1	5	0	6
7. Jaguar Y	0	0	13	13
8. Jaguar Z	0	0	1	1
Total	**15**	**11**	**19**	**45**

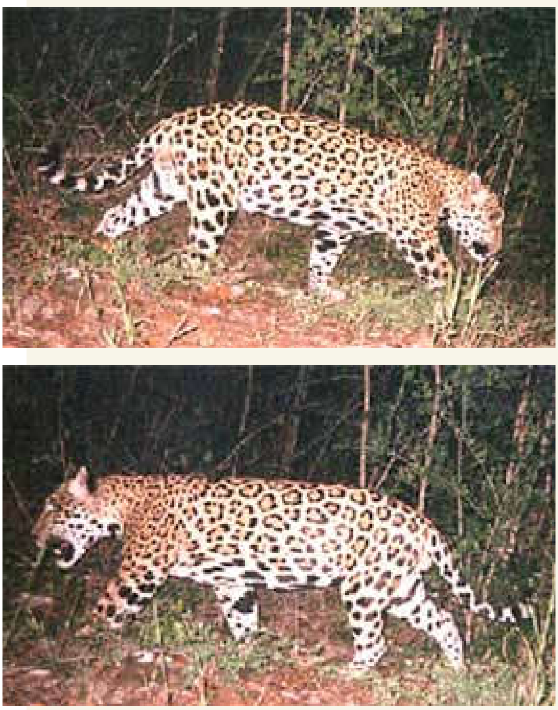


Figure 2. Photographs of both flanks of Jaguar Francisco (2004).

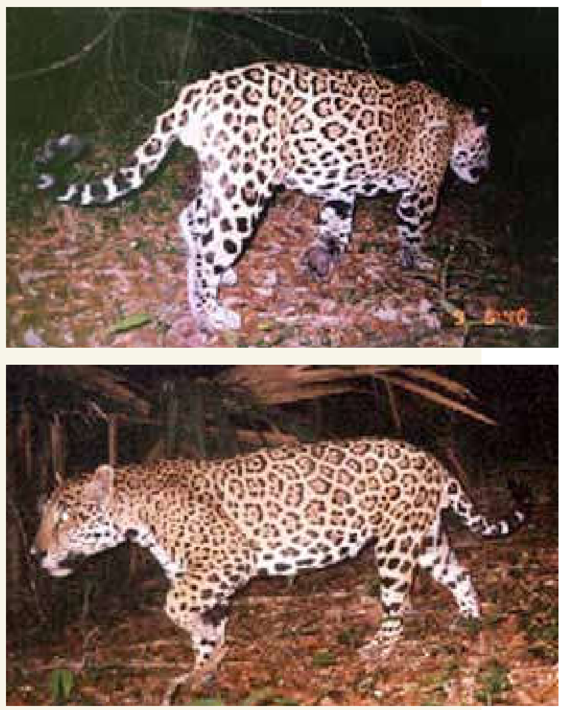


Figure 3. Photographs of both flanks of Jaguar 2 (2004).

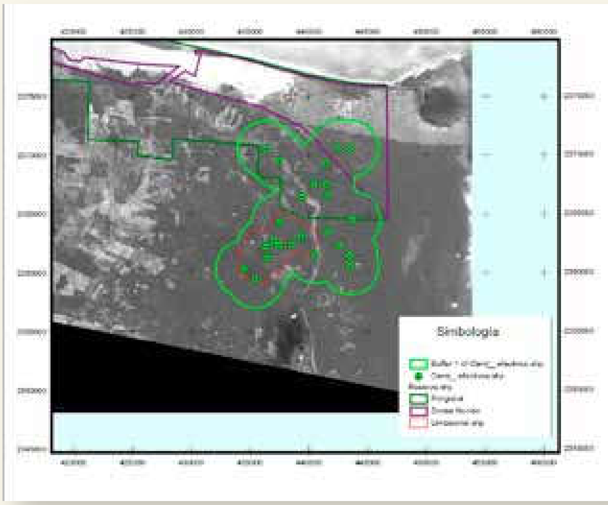


Figure 4.
Stations and effective sampling area in Ría Lagartos 2004. Coordinates are in UTM (Zone 16).

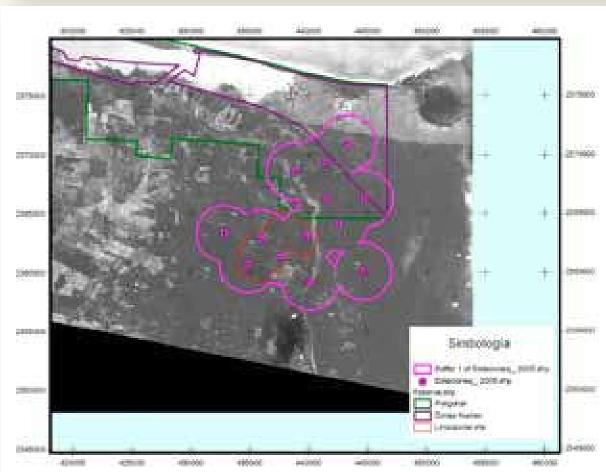


Figure 5.
Stations and effective sampling area in Ria Lagartos 2005. Coordinates are in UTM (Zone 16).

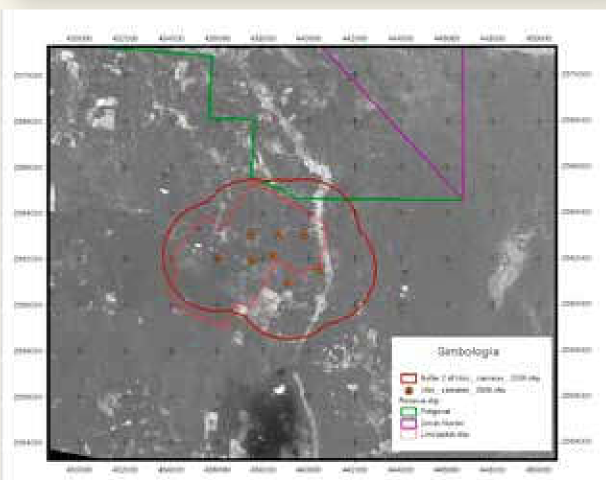


Figure 6.
Stations and effective sampling area in Ría Lagartos 2006. Coordinates are in UTM (Zone 16).

the area was struck by a Category 5 hurricane in October 2005. The hurricane caused severe damage to vegetation and flooded the region for several months, which may have caused a general readjustment of jaguar territories towards the periphery of the study area, which was the worst affected. Taking these considerations into account, it is worth underlining that estimated population densities were similar to those obtained for the Calakmul region, in the south of the peninsula (Ceballos *et al.*, 2002; Chávez *et al.*, this volume).

In the northeast of the peninsula, there are 400,000 hectares of forest, including the Ría Lagartos and Yum Balam federal reserves (Figure 7). Before the 2005 hurricanes and the forest fires of May 2006, about 70% of the forests of the region had a good conservation status, and the rest showed moderate to severe levels of disturbance (PPY, 2005). Considering a density of 2 to 6 jaguars/100 km^2, it is possible to make a cautious population estimate of around 80 to 240 individuals in the north east of the Yucatan Peninsula (Table 3). In other words, the region has one of the largest jaguar populations in Mexico and is therefore a high-priority area for jaguar conservation.

However, the region is currently facing serious connectivity problems with the other Maya Forests to the south. The forests to the west have practically disappeared due to the construction of roads, which leads to continuous degradation of ecosystems along their layout. The south of the region is fragmented by a system of roads of various categories. The largest is the freeway between the cities of Mérida and Cancún, particularly the stretch between El Ideal and Cancún; the southeastern corner is occupied by the city of Cancún. The western corner of the matrix is formed by an

Table 2. Results of jaguar camera trapping in Ría Lagartos, Quintana Roo between 2004 and 2006

	2004	2005	2006
Sampling effort	34 days	89 days	97 days
Closed population test	*Z*=-0.357 *p*=0.36	*Z*=-2.569 *p*=0.0051*	*Z*=0.46 *p*=0.68
Model	M(h)	M(h)	M(o)
Estimated capture probability	0.083	0.038	0.055
Estimated population with CAPTURE	6±0.63	3±0.28	3±0.16
Estimated sampling area (km^2)	183	165	48.5
Estimated density (individuals/100 km^2)	3.28±0.34	1.82±0.17	6.18±0.33

* Did not behave as a closed population

M(h)= Jackknife model, variable capture probability

M(o)= Equal capture probability model

imaginary line from the harbor of El Cuyo to the town of El Ideal; the line can be considered as the eastern limit of the farming frontier in Yucatán (Figure 7; Lazcano *et al*., 1995). In spite of this, the region is connected to the almost continuous forests stretching from this area to Calakmul and Sian Ka'an Biosphere Reserves (see also chapters by Chávez *et al*. and Navarro *et al*., this volume).

Therefore, it is essential to make an assessment to determine the necessary conservation, mitigation and restoration measures to halt the loss of connectivity between the forests in the north and south of the peninsula. Corridors with wildlife crossings in roadways need to be created to increase and reestablish habitat connectivity. This will largely determine the possibility of maintaining a viable jaguar population in the long term in the north of the Yucatan Peninsula.

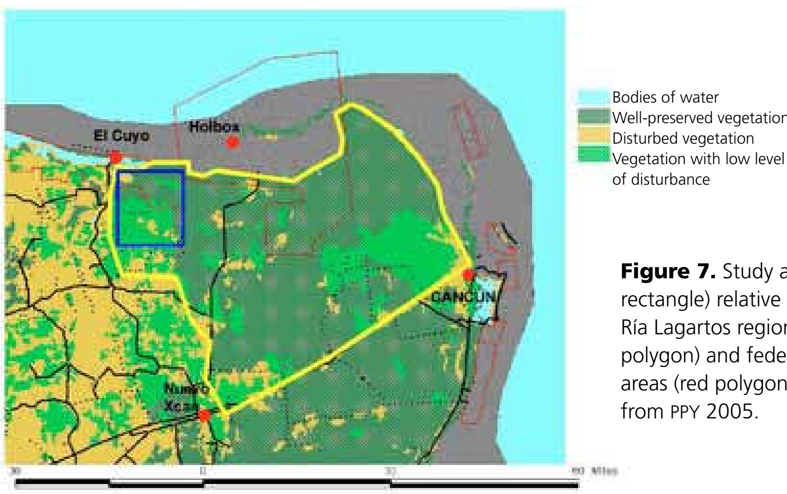


Figure 7. Study area (blue rectangle) relative to the Yalahau-Ría Lagartos region (yellow polygon) and federal protected areas (red polygons). Image taken from PPY 2005.

Table 3. Population size in protected areas in the north east of the Yucatan Peninsula

Reserves	Surface (km²)	Population size 3/100 km²	Population size 6/100 km²
Reserves of the wetlands in the north of the Yucatan Peninsula (RWNY)	1400	42	84
Yalahau-Ría Lagartos region (including RWNY)	4000	120	240

The RWNY are: Ría Lagartos Biosphere Reserve, Yum Balam Flora and Fauna Protection Area and Bocas de Dzilam State Reserve.

Acknowledgments
We would like to thank the landowners and communities of Nuevo León, El Limonar, Tesoco Nuevo, Tekal Nuevo, El Nuevo Mundo and Santa María, in the municipality of Tizimín, Yucatán, for all their help, interest and facilities provided to carry out the study on their land; Pronatura Península de Yucatán A.C., the Instituto de Ecología-UNAM and Fort Worth Zoo for making this study possible; the Association of Zoos and Aquariums (AZA), which provided most of the funds for the project through its Conservation Endowment Fund; the North American Wetlands Conservation Council (NAWCA), the US Fish and Wildlife Service (USFWS), The Nature Conservancy (TNC), Grupo Modelo, Palm Beach Zoo, Albuquerque Biological Park, Oklahoma City Zoo, Erie Zoo, Tulsa Zoo and Living Museum, Sedgwick County Zoo, Dallas World Aquarium, Fort Worth Zoo Chapter of the American Association of Zookeepers, Wildlife World Zoo, and El Paso Zoo for their financial support; the Management of the Ría Lagartos Biosphere Reserve, for all the facilities and support provided; Joann Andrews and Robert Wiese for their constant advice, enthusiasm and encouragement.

JAGUARS IN YUM BALAM AND NORTHERN QUINTANA ROO

Carlos J. Navarro Serment, José Francisco Remolina Suárez, and José Juan Pérez Ramírez

Resumen

El Área de Protección de Flora y Fauna Yum Balam, ubicada en el extremo norte de Quintana Roo, forma parte de una de las regiones prioritarias para la conservación del jaguar. El área se encuentra en excelente estado de conservación y comprende las selvas tropicales bajo protección más norteñas del continente. Es una de las zonas en donde la conservación del jaguar tiene mayores posibilidades de éxito a largo plazo. Desde 2004, se ha evaluado la presencia de jaguar, por medio de entrevistas con habitantes de la región y registros, así como información sobre el hábitat e interacciones con actividades pecuarias en Yum Balam, su zona de influencia y con el resto de las principales reservas de la mitad norte de Quintana Roo. Se recopilaron 149 registros de jaguar en la región, de los cuales hubo 70 en Yum Balam, lo que demuestra la presencia de jaguar en la mayor parte del área, incluyendo las zonas intermedias entre las principales reservas. Sin embargo, el escaso manejo del ganado, la falta de información sobre la importancia biológica del jaguar, la inadecuada aplicación de la ley, la escasa vigilancia y la pérdida del respeto tradicional de la cultura maya hacia la especie: propician la cacería ilegal. Asimismo, la pérdida de hábitat en la región debido al desarrollo de la frontera urbana, agropecuaria y turística es muy acelerada, por lo que es de suma importancia tomar medidas tendientes a evitar la fragmentación.

Palabras clave: jaguar, Yum Balam, Otoch Maax Yetel Kooh, Sian Ka'an, Quintana Roo, conservación, depredación.

Abstract

The Yum Balam Flora and Fauna Protected Area is located on the extreme north of the state of Quintana Roo, is part of one of the priority zones for jaguar conservation. The area shows an excellent conservation state and includes the northernmost protected tropical forests in the continent. It is also one of the places where jaguar conservation has better chances to succeed in the long-term. Since 2004, interviews with local people have been conducted and jaguar records collected, as well as habitat data and information about interactions with human activities in Yum Balam, its influence zone and in the main protected areas from the northern half of Quintana Roo. 149 jaguar records have been collected, 70 from Yum Balam, proving that the species is still present throughout the area, including those zones connecting the different reserves. However, the poor or non-existent cattle manage-

ment, the lack of information and law enforcement and the diminishing of the traditional Mayan respect for the jaguar, are causing the continued illegal hunting of the species. Habitat loss in the region due to the expansion of urban and tourist are taking place at a very fast rate; it is very important to take actions preventing habitat fragmentation.

Keywords: conservation, jaguar, predation, Otoch Maax Yetel Kooh, Quintana Roo, Sian Ka'an.

Introduction

Yum Balam Fauna and Flora Protection Area (Yum Balam means "lord jaguar" in Mayan language) covers a surface of 154,052 hectares. It contains a great variety of wild animals, including five felid species. Yum Balam is located at the northern end of the municipality of Lázaro Cárdenas in the state of Quintana Roo, between coordinates 21° 43'-21° 14' N and 87° 32'-87° 07' W. Most of Yum Balam has an excellent conservation status, and the area is part of the northernmost tropical forests on the continent. The jaguar (*Panthera onca*) seems to have a favorable status in the area, although some very important aspects of its biology –population density, abundance and habitat use– are still unknown (Sanderson *et al.*, 2002a).

Yum Balam is in one of the four high-priority regions for jaguar conservation identified by the Mexican Technical Advisory Subcommittee for Jaguar Conservation and Management (Ceballos *et al.*, 2006) and one of the "Priority 1 Areas" for the conservation of the species (Chávez and Ceballos, 2006). Along with the rest of the forests of the Yucatan Peninsula, known as Maya Forest, this region is one of the areas where jaguar conservation has the best chances of success in the long term. Other important protected areas for jaguar conservation in the north east of the peninsula are Sian Ka'an Biosphere Reserve, Otoch Ma'ax Yetel Kooh Flora and Fauna Protection Area in Quintana Roo, and Ría Lagartos Biosphere Reserve in Yucatán (Semarnat-Conabio, 1995).

The aim of this study was to assess the status of the jaguar in the north east of the Yucatan Peninsula in order to develop tools and strategies for its management and conservation, especially in Yum Balam, Otoch Ma'ax Yetel Kooh and their areas of influence.

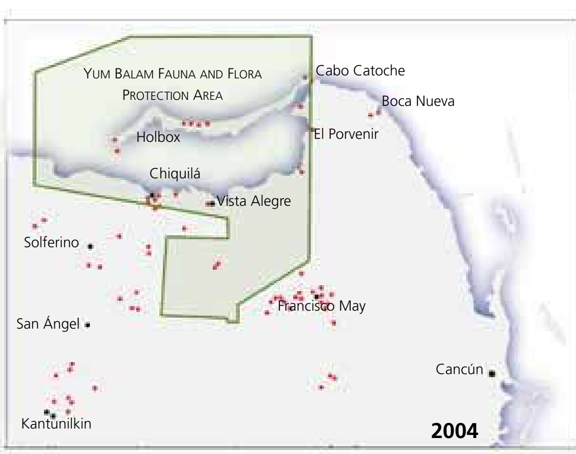
Methods

In 2004 and 2005, we conducted interviews to determine the presence and current status of the jaguar in the protected areas Yum Balam, Sian Ka'an, Otoch Ma'ax Yetel Kooh, Ría Lagartos and intermediate zones. They were informal interviews, aimed at obtaining answers to 20 basic questions (Appendix I) on hunted or observed individuals and information on the place and date of the record, vegetation type, etc. In 2004, we conducted 58 interviews in 13 villages and communities in Yum Balam and its area of influence. In 2005, we conducted 97 interviews in 40 towns, villages and communities in and around Yum Balam, Otoch Ma'ax Yetel Kooh, Sian Ka'an, Ría Lagartos and intermediate zones. Recent records were obtained by means of tracks or other sign; we camped and surveyed the whole area on foot, by car or motorcycle, mainly at dawn and dusk to increase the chances of jaguar sightings (Karanth *et al.*, 2002). In several sites with no suitable open spaces or good substrate to obtain track marks, we placed 1.5 x 1.5 m sand and mud traps along appropriate trails and periodically reviewed them in the morning. We continually monitored events of predation on livestock or domestic animals blamed on felids –especially jaguars and pumas– in villages near Yum Balam and Otoch Ma'ax Yetel Kooh.

Results and discussion

Based on the interviews and direct records of tracks, skins and photographs, we obtained 149 jaguar records in the north east of the Yucatan Peninsula; 70 were obtained in the Yum Balam area, where the effort was greater (Figures 1 and 2).

The interviews conducted show that illegal hunting of jaguars and other felids is still widespread in the region. We detected two main jaguar hunting areas, one near the town of Kantunilkin, the municipal seat of Lázaro Cárdenas, and one in the community of Francisco May. Both places are located at opposite ends of Yum



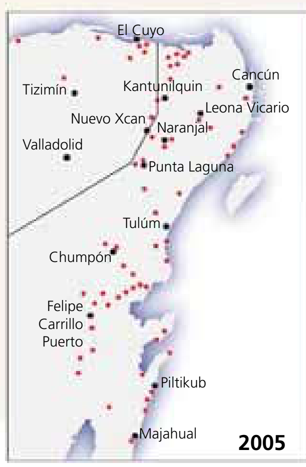


Figure 1. Approximate location of jaguar (*Panthera onca*) records obtained in 2004-2005 in the north east of the Yucatan Peninsula, Mexico.

Balam Flora and Fauna Protection Area. The 10 jaguars hunted in 2004 (38% of the total number of records for that year) were killed around these communities. Kantunilkin is where livestock farming is most important in the area, and livestock predation by jaguars and pumas is regularly reported in farms nearby. The same applies to Francisco May, although cattle are scarce in this community and predation mainly affects sheep and swine. The defense of domestic animals was put forward as the main reason for hunting. The communities of Kantunilkin and Francisco May exert a great hunting pressure on their surroundings because of their size and intensive use of natural resources respectively. The decline in the wild prey of wild felids –especially deer and peccaries– may be a triggering factor of predation on livestock (Crawshaw, 2002; Treves and Karanth, 2003).

Most people in these communities perceive jaguars as competitors for their favorite bushmeat species –especially white-tailed deer and peccaries– which contributes to their lack of acceptance of the species. Most people surveyed consider that sheep and calves are important components in the jaguar's diet. These animals ranked fifth and sixth respectively among a list of 14 species mentioned, behind white-tailed deer, white-nosed coati, collared peccary and paca. In contrast, communities that are mainly devoted to crop farming, fishing or other activities, such as Nuevo Durango, Chiquilá and San Pablo, showed less rejection to the jaguar's proximity.

Figure 2.
Jaguars photographed in the limits of Yum Balam Fauna and Flora Protection Area, Quintana Roo.

The communities of Kantunilkin, San Pablo and Francisco May were the only ones where the idea of making a profit with jaguar hunting was mentioned. Apart from the payment offered by some livestock farmers for killing felids that attack their livestock (between 500 and 5,000 mexican pesos), hunters sell the skins in the community or in large cities such as Cancún, Valladolid and Mérida. The money hunters obtain for a jaguar skin ranges from 800 to 10,000 pesos. Jaguar teeth are highly valued, and hunters can obtain 200 to 300 pesos per canine.

A loss of cultural identity has been observed; in Maya culture, the jaguar has traditionally represented a sacred being: the most powerful of the animals in the forest, which is admired and respected. Communities are now more exposed to other ideas, which has led to considering the jaguar as just an animal among others that can be hunted with impunity. The number of jaguars injured by gunfire is another triggering factor of livestock predation. Most peasants walking to their fields on forest trails will shoot any felid they come across. Regardless of whether the felids are responsible for livestock attacks or not, they are killed or left injured or unable to hunt natural prey, in which case they target easy prey such as livestock (Hoogesteijn *et al.*, 2002).

Another determining factor in predation by jaguars and pumas in the region is livestock management. Most livestock farms are small and family-owned, with little or no management of livestock. The animals spend most of the time outdoors, in pastures that are normally delimited only by a barbed wire fence. Depending on the possibilities of each farmer and the amount of land available, cattle, horses and sheep may be moved to different pastures according to their availability. In the case of cattle, many livestock farmers do not have a breeding season, health plans or records of palpations, births and mortality. Cows that are about to calve usually stay in the same area as the rest of the cattle and calves are not transferred to a special enclosure. Many pastures are right next to the forest, which starts just on the other side of the fence, or inside the enclosure. Domestic pigs and even sheep may wander freely around the houses, as well as chickens and turkeys. The fact that domestic animals are subjected to little or no management contributes to predation (Hoogesteijn *et al.*, 2002; Shivik, 2006).

It is important for governmental and non-governmental organizations to implement awareness-raising and educational campaigns on proper livestock management among the people in the region to reverse this trend, and on the importance of the jaguar, to achieve protection of the species and guarantee its survival.

The expansion of agriculture and tourism is fragmenting the habitat at a fast rate, particularly along the north east of the peninsula, on the Caribbean coast of Quintana Roo (Roy Chowdhury, 2006; Turner II *et al.*, 2001). Protected areas are a very important protective element in these regions. In this study, numerous records of jaguars and other felids were obtained within and around Sian Ka'an, Yum Balam and Otoch Ma'ax Yetel Kooh; however, it is vital to maintain habitat connectivity to prevent protected areas from becoming isolated and ensure gene flow between populations in the northern reserves and Sian Ka'an, as well as the protected areas in the south of the Yucatan Peninsula, such as Calakmul Biosphere Reserve. To guarantee long-term conservation of the jaguar, it is also essential to create and implement a regional conservation plan involving protected areas, landowners, local people and civil society.

Appendix I

Basic questionnaire used in interviews with local people

1. Do you know if there are jaguars in this area (in the last 5 years)?
2. How do you know there are jaguars in this area?
3. Do you know whether the jaguars are breeding (how do you know that)?
4. Do you think there are more, less or the same number of jaguars as before?
5. Which do you think are the main prey of jaguars?
6. Do you think the fact that there are jaguars is good, bad, or makes no difference?
7. Why do you think it is bad?
8. Why do you think it is good?
9. Why are jaguars hunted?
10. Do jaguars kill domestic animals?
11. Would you shoot a jaguar if you had a chance?
12. Do you think the fact that there are pumas is good, bad, or makes no difference?
13. Why do you think it is bad?
14. Why do you think it is good?
15. Do you think the fact that there are margays is good, bad, or makes no difference?
16. Why do you think it is bad?
17. Why do you think it is good?
18. Do you think the fact that there are jaguarundis is good, bad, or makes no difference?
19. Why do you think it is bad?
20. Why do you think it is good?

Appendix 2

Places where interviews were conducted		
Communities visited	**Municipality**	**State**
Tres Reyes	Felipe Carrillo Puerto	Quintana Roo
Santa Amalia	Felipe Carrillo Puerto	Quintana Roo
Felipe Carrillo Puerto	Felipe Carrillo Puerto	Quintana Roo
Uh-may	Felipe Carrillo Puerto	Quintana Roo
Rancho Alegre	Solidaridad	Quintana Roo
Pulticub	Othón P. Blanco	Quintana Roo
Tulúm	Solidaridad	Quintana Roo
Cobá	Solidaridad	Quintana Roo
Pino Suárez	Solidaridad	Quintana Roo
Muyil-Chuyaxché	Felipe Carrillo Puerto	Quintana Roo
Chunpón	Felipe Carrillo Puerto	Quintana Roo
Chun-on	Felipe Carrillo Puerto	Quintana Roo
Chun-ya'a	Felipe Carrillo Puerto	Quintana Roo
Rancho Grande	Solidaridad	Quintana Roo
Xpu-ha	Solidaridad	Quintana Roo
Playa Maroma	Solidaridad	Quintana Roo
Ejido Playa del Carmen	Solidaridad	Quintana Roo
Ejido Puerto Morelos	Benito Juárez	Quintana Roo
Central Vallarta	Benito Juárez	Quintana Roo
Ejido Bonfil	Benito Juárez	Quintana Roo
Ignacio Zaragoza	Lázaro Cárdenas	Quintana Roo
San Francisco	Lázaro Cárdenas	Quintana Roo
San Cosme	Lázaro Cárdenas	Quintana Roo
Naranjal	Lázaro Cárdenas	Quintana Roo
El Ideal	Lázaro Cárdenas	Quintana Roo
Cedral	Lázaro Cárdenas	Quintana Roo
Tres Reyes	Lázaro Cárdenas	Quintana Roo
Nuevo Xcan	Lázaro Cárdenas	Quintana Roo
Punta Laguna	Lázaro Cárdenas	Quintana Roo
Nuevo Durango	Lázaro Cárdenas	Quintana Roo
Campamento Hidalgo	Valladolid	Yucatán
Punta Laguna	Valladolid	Yucatán
Tizimín	Tizimí	Yucatán
Sucopa	Tizimín	Yucatán
Colonia Yucatán	Tizimín	Yucatán
El Cuyo	Tizimín	Yucatán
Kantunilkin	Lázaro Cárdenas	Quintana Roo
San Ángel	Lázaro Cárdenas	Quintana Roo
Solferino	Lázaro Cárdenas	Quintana Roo
San Eusebio	Lázaro Cárdenas	Quintana Roo
Chiquilá	Lázaro Cárdenas	Quintana Roo

PART II

CONSERVATION AND MANAGEMENT

FIRST NATIONAL JAGUAR SURVEY

Cuauhtémoc Chávez, Gerardo Ceballos,
Rodrigo A. Medellín, and Heliot Zarza

Resumen

Las prioridades de conservación de especies que tienen grandes áreas de actividad, como los jaguares, deben de planearse a diferentes escalas (local a geográfica), además de tomar en cuenta el tamaño del área de actividad, el área de distribución y los distintos hábitat, y sus posibles interacciones con las actividades humanas. El Censo Nacional del Jaguar y sus Presas (CENJAGUAR), pretende realizar una estimación del jaguar y sus presas en sitios prioritarios para su conservación. Para ello se usará la técnica de trampas-cámara, que ha sido ampliamente usada para estimar las poblaciones de jaguar y también las abundancias de sus presas. Se recomienda una densidad de tres estaciones de muestreo por cada 9 a 16 km^2 para el jaguar y sus presas con grandes áreas de actividad. Para las presas con áreas de actividad pequeña se recomiendan nueve estaciones en 0.2 km^2. Se recomienda el uso de modelos de captura-recaptura para analizar los aspectos demográficos; sin embargo, se deben considerar aspectos como el tamaño de la muestra para generar una estimación estadísticamente robusta de densidad. El CENJAGUAR es el primer esfuerzo para llevar a cabo una evaluación de su situación poblacional a nivel nacional en México. No se han realizado estudios similares de esta magnitud en ningún otro país donde habita el jaguar. En este sentido, el proyecto marcará nuevos estándares para la conservación de la especie a nivel mundial. Esta información servirá para determinar las áreas prioritarias para la conservación del jaguar a escala local (ejidos), regional (nivel estatal) y geográfica (nivel país). La estrategía identificará las áreas que deben tener un manejo compatible con la conservación del jaguar y sitios adecuados para establecer corredores biológicos que una a los sitios prioritarios.

Palabras clave: censo nacional, estimación poblacional, presas, trampas-cámara.

Abstract

The priorities of conservation of species that have large home ranges, as the jaguars, have to of be planned at different scales, besides bearing in mind the size of the area of activity, the distribution area and different habitat, and his possible interactions with the human activities. The National Census of the Jaguar and its Preys (CENJAGUAR) will estimate the population status of jaguar and its preys in priority sites for his conservation. Cameras-traps, which have been widely used to estimate the populations of jaguars, will be used to estimate abundances. A density of three sampling stations for every 9 to 16 km^2 for jaguars *and preys with big areas of activity, whereas, for the preys with areas of small activity nine stations in 0.2 km^2. We recommend, the models' use of capture re-captures to analyze the demographic aspects; nevertheless, we must consider aspects to be the size of the sample to generate a statistically robust estimation of density, by what the use of indexes of abundance can be adapted, provided that the design this one standardized. The CENJAGUAR is the first effort to carry out an evaluation of his population national situation. There have not been realized similar studies of this magnitude in any other country where he inhabits the jaguar. In this respect, the project will mark new standards for the conservation of the species worldwide. This information will serve to determine the priority areas for the conservation of the jaguar to local scale (common lands), regional (state level) and geographical (level country). The strategy will identify the areas that must have a managing compatible with the conservation of the jaguar and sites adapted to establish biological corridors that one to the priority sites*

Keywords: National census, population estimate, prey, camera-traps.

Introduction

Most populations of large carnivores are threatened or endangered due to anthropogenic factors (Treves and Karanth, 2003; Woodroffe and Ginsberg, 1998). Although the jaguar (*Panthera onca*) is broadly distributed species, it has lost more than half of its historical range because of habitat destruction and fragmentation, illegal hunting, a decline in its prey, and exotic diseases (Ceballos *et al.*, 2002; Chávez, 2006; Chávez *et al.*, this volume; Sanderson *et al.*, 2002).

The jaguar is endangered in Mexico; yet, there has not been a thorough and updated assessment on the status of its populations to be able to design appropriate strategies for its conservation (Ceballos *et al.*, 2006). The status of the jaguar and its population size have never been determined simultaneously in a whole country. The 2nd Symposium "The Mexican Jaguar in the 21st Century: Current Status and Management" was held in 2006. It brought together about 50 experts from universities, social organizations, the federal government and the private sector. One of the conclusions of the symposium was the need to implement specific actions on a national scale to reduce the extinction risk of the jaguar. The findings obtained in the symposium are the basis of a strategy for the long-term conservation of the species with objectives, targets and specific actions, including the preparation of a national survey (Ramírez and Oropeza, this volume).

The objectives of the first National Survey of the Jaguar and its Prey (CENJAGUAR) are to assess the population density of the jaguar and its prey in Mexico, determine jaguar habitat available in Mexico, and identify conservation requirements of the jaguar and its prey in priority areas. It aims at assessing the distribution and population status of the species in areas where it is currently uncertain whether the jaguar occurs or its populations are stable, whether there is suitable habitat and enough prey for the species to survive, and in places previously identified as priority areas (Ceballos *et al.*, 2006; Chávez and Ceballos, 2006; Zarza *et al.*, this volume).

CENJAGUAR involves monitoring jaguar and prey populations and jaguar habitat at a large scale. It is therefore necessary to use a relatively easy and reliable method so that demographic data can be standardized. If the study persists in the long term, it will be possible to assess habitat and population viability on a regular basis. If this effort is made in parallel to other actions, such as those dealing with conflicts with livestock, it will lead to better understanding of human-jaguar relations. Along with national programs, such as Proarbol, UMAs (Wildlife Management Units) and the promotion of jaguar habitat and prey conservation, this kind of actions will lead to a better quality of life for local people.

Standardized protocol

In an attempt to standardize sampling designs, Silver *et al.* (2004) and Medellín *et al.* (2006) published two protocols to study the jaguar based on methods originally used to study tigers (*Panthera tigris*) in India by means of capture-recapture procedures (Karanth, 1995; Karanth and Nichols, 1998; 2002; Lynam, 2002).

The first protocol focuses on the use of camera traps in sampling to estimate jaguar abundance; it uses established capture-recapture procedures to analyze closed populations and spot patterns to identify individuals photographed. The date is printed in every photograph, which makes it possible to measure days or other units of time as discrete sampling events. This protocol has been used successfully to estimate the abundance of the jaguar and its prey (Maffei *et al.*, 2004; Silver *et al.*, 2004; Weckel *et al.*, 2006). In Mexico, it has been used in vegetation types as diverse as cactus scrub, tropical deciduous forest, semi-evergreen forest and tropical rainforest (Azuara, 2005; Azuara and Medellín, this volume; Ceballos *et al.*, 2005; López-González and Brown, 2002; Núñez *et al.*, 2000).

The second protocol was specifically developed for Mexico (Medellín *et al.*, 2006). It is the result of the working group on surveys and monitoring in the 1st Symposium "The Mexican Jaguar in the 21st Century: Current Status and Management" held in Cuernavaca, Morelos (Chávez and Ceballos, 2006). It estimates abundance using different methods: 1) search for sign, including tracks, 2) use of camera traps 3) scats and genetic analysis in the laboratory and 4) capture and radio telemetry.

National survey of the jaguar and its prey

This is the first effort to carry out a country-wide assessment of the status of the jaguar. No similar studies of this scale have been carried out in any of the other range countries of the jaguar. The project will set new standards for the conservation of the species worldwide. This information will be used to determine priority areas for jaguar conservation on a local (ejidos), regional (states) and national (country) level. The strategy will identify areas whose management must be compatible with jaguar conservation and suitable places to establish biological corridors connecting priority areas.

Design of the survey

The design of the survey must involve a preliminary assessment of jaguar presence-absence in predetermined areas. Regional and national assessments are based on priority areas for jaguar conservation (Table 1; Ceballos *et al.*, 2006). It is necessary to hold previous meetings with any organizations that might be interested in participating in the process. It is also important to obtain surveys with basic information about socioeconomic conditions and knowledge about wild animals in general and the jaguar and its prey in particular. This must be verified in the field to corroborate the presence of jaguars. Finally, results should be standardized qualitatively and quantitatively. The basis for this work will be the assessment suggested by Medellín *et al.* (2006), which includes all the necessary tools to conduct the assessment.

The existence of a population or individuals must be verified. This will be done by looking for tracks and other sign and using camera traps. When using camera traps, it is important to take certain issues into account to develop correct estimates (Karanth and Nichols, 2002). The survey is based on the use of camera traps, the safest and most viable method to obtain the necessary information on jaguar abundance and density throughout its range in different habitat types (Karanth and Nichols, 1998; Lynam, 2002; Medellín *et al.*, 2006). For the purposes of this survey, a sampling station consists of one or two camera traps placed in one site. A sampling cell is the minimum home range of a female (9 km^2) in a certain amount of time, 20 days for practical and assessment purposes.

The following considerations must be taken into account regarding the design of CENJAGUAR:

1. All the individuals in a sampling area have the same probability of being captured –i.e., photographed– by one or more camera stations during the study. The design of the study must ensure that there are no gaps in the study area, to avoid situations in which an individual can move in its home range with no probability of being photographed. In each sampling cell, camera traps can be strategically placed to maximize capture probability, e.g., near scratching, tracks, scats, along hunting trails and near bodies of water.

2. Sampling time and duration shall be determined according to seasonal climatic conditions and access to the sampling area. In most areas (Table 1) this kind of study can be carried out in the dry season (January-May). However, this has to be defined with each researcher on the basis of seasonal considerations, accessibility and knowledge of the demographic parameters of the area or similar areas. Camera trapping can take 20 to 90 consecutive days. A sampling period exceeding 90 consecutive days may lead to violating the closed population assumption (Karanth and

Nichols, 1998). Although there are few data available on the natural history of the jaguar, accumulation curves for new individuals in tropical environments show that it takes about 20 days on average to obtain jaguar photographs in a sampling station (C. Chávez, unpublished data). Cameras must be checked every 10 days, and camera trap placement and removal must not be counted in the sampling effort.

3. Sampling effort will depend on the area. In rugged areas, it will take 5 to 10 days to place the camera traps and 4 to 8 days to remove them. Two to three camera

Table 1. Regions and states where CENJAGUAR will be conducted in Mexico

Region	State	Name	Institution/Organization
North	Sinaloa	Yamel Rubio	Universidad Autónoma de Sinaloa
North	Sonora	Gerardo Carreón	Naturalia A.C.
North	Sonora	Oscar Moctezuma	Naturalia A.C.
North	Sonora	Carlos Lopéz	Universidad de Querétaro
North	Sonora	Octavio C. Rosas Rosas	Colegio de Posgraduados, Unidad San Luis Potosí
North	San Luis Potosí	Octavio C. Rosas Rosas	
North	Tamaulipas	Arturo Caso Aguilar	Proyecto Felinos de México A.C.
Central Pacific	Jalisco	Rodrigo Núñez Pérez	Fundación Ecológica de Cuixmala A.C.
Central Pacific	Guerrero	Rodrigo Núñez Pérez	Fundación Ecológica de Cuixmala A.C.
Central Pacific	Michoacán	Ricardo Legaria	Gobierno del Estado de Michoacán
Central Pacific	Nayarit	Erik Saracho Aguilar	Hojanay A.C. Hombre Jaguar Nayarit
Southern Pacific	Chiapas	Rodrigo A. Medellin	Instituto de Ecología UNAM
Southern Pacific	Chiapas	Epigmenio Cruz	IHNE Chiapas (Sierra Madre de Chiapas)
Southern Pacific	Oaxaca	Iván Lira Torres	Zoológico de Aragón
Southern Pacific	Oaxaca	Diego Wooldrich/ Iván Lira Torres	Zoológico de Aragón
Yucatan Peninsula	Quintana Roo	Cuauhtémoc Chávez	Instituto de Ecología UNAM
Yucatan Peninsula	Quintana Roo	Gerardo Ceballos	Instituto de Ecología UNAM
Yucatan Peninsula	Quintana Roo	Heliot Zarza	Instituto de Ecología UNAM
Yucatan Peninsula	Quintana Roo	Marco Lazcano	El Edén
Yucatan Peninsula	Yucatán, Campeche	Juan Carlos Faller	Pronatura Península de Yucatán A.C.
Yucatan Peninsula	Quintana Roo	Francisco Remolina	ANP Yum Balam, Conanp
Yucatan Peninsula	Quintana Roo	Carlos Navarro	Onca A.C.

stations can be placed daily, one daily in areas far from the base camp. This depends greatly on the type of vegetation and accessibility of the area. It takes 2 hours on average to place each camera trap.

4. The size of the sampled area is essential. The CAPTURE program works best with populations ≥ 15-20 individuals, which is not very viable in most situations because of the low density of the jaguar and logistic and economic limitations. A minimum sampling area of 64-200 km^2 is required in areas with high densities (Figure 1; Medellín *et al.*, 2006). The highest densities recorded are 7-9 individuals/100 km^2 (Chávez, 2006; Chávez *et al.*, this volume; Maffei *et al.*, this volume). Areas with low densities require a minimum sampling area of 400-750 km^2 (Figure 2). This is because the minimum density recorded for the jaguar is less than one individual/100 km^2 (S. Avila, pers. comm.; Paviolo *et al.*, 2005; Rosas-Rosas et al., 2008; C. López-González, pers. comm.).

5. The size of the sampling area can be determined according to logistic limitations, funding or equipment resources, availability of the working team, or jaguar density. It is necessary to determine when to estimate the population or abundance of a species through sampling. The sampling area must be delimited within suitable and unsuitable habitat for the jaguar. Suitable habitat can be defined as an area with plant cover and evidence of habitat use by jaguars, whereas unsuitable habitat is habitat with very little evidence of jaguar presence. The sampling area is divided into sampling cells of equal size that must not exceed the minimum home range of an adult female (10 to 65 km^2), depending on sampling time and vegetation type.

6. The arrangement and number of camera traps should be done as follows: Each sampling cell may contain 3 sampling stations 1 to 4 km apart (Figure 1). In cases where most sampling cells have unsuitable habitat for the jaguar and two sampling stations are relatively close to each other –less than 1 km apart– only one camera station should be used (Figure 2). The number of sampling stations should be limited; even with 20 sampling stations, it would only be possible to sample an area of 250 km^2 at once. The most important study so far on the ecology of the puma was conducted in an area of 2,059 km^2 (Logan and Sweanor 2001). This suggests that the area recommended to monitor the jaguar population in some areas should cover 6,000-8,000 km^2, which is very difficult to implement for logistic reasons. On the other hand, if the cameras are periodically moved or sampling time increases too much, there is a risk of violating the closed population assumption.

The minimum number of stations is 18/100 km^2, that is, 3 stations/16 km^2, the minimum home range for a female in 20 to 60 days (C. Chávez, pers. comm.; Soisalo and Cavalcanti, 2006). At least 4 out of every 9 stations must have two cameras (double stations). Therefore, at least 26 cameras are required for the jaguar survey, with a total number of 18 stations (Figure 1).

Prey species

Sampling with camera traps makes it possible to estimate the abundance of prey species, particularly in areas where animals are difficult to see. Cameras can be placed on trails or paths used by wildlife to generate an index of prey density based on the number of photographs taken per sampling effort. For example, number of photographs of peccaries/100 trap days. However, scope of the relation between the index and actual prey density or abundance remains unknown (Karanth and Kumar, 2002). Due to the habits and sizes of most potential jaguar prey, there will be two types of sampling areas, one for large species with a minimum home range greater than 1 km^2 and one for smaller species. For large species, the considerations of camera trap design are similar to the jaguar's, with a few differences. Sampling will be simul-

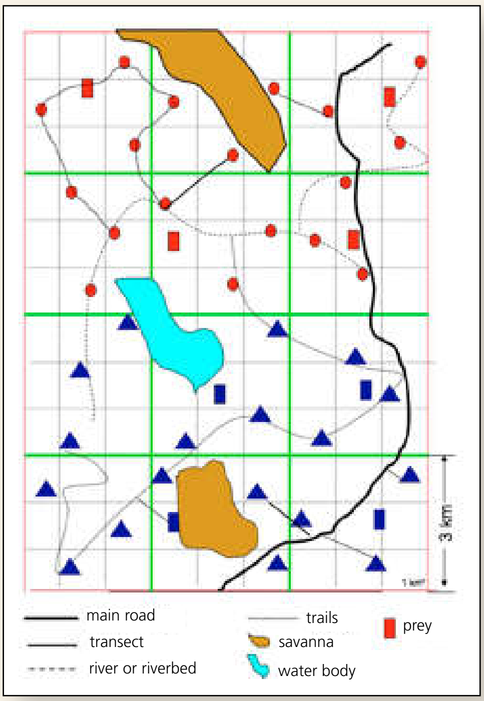


Figure 1. Sample design with camera traps in good-quality habitat or habitat with good plant cover. Sampling cell size is 9 km². Circles and triangles show the position of camera trapping stations. The first sampling period is shown in red; the second one is shown in blue.

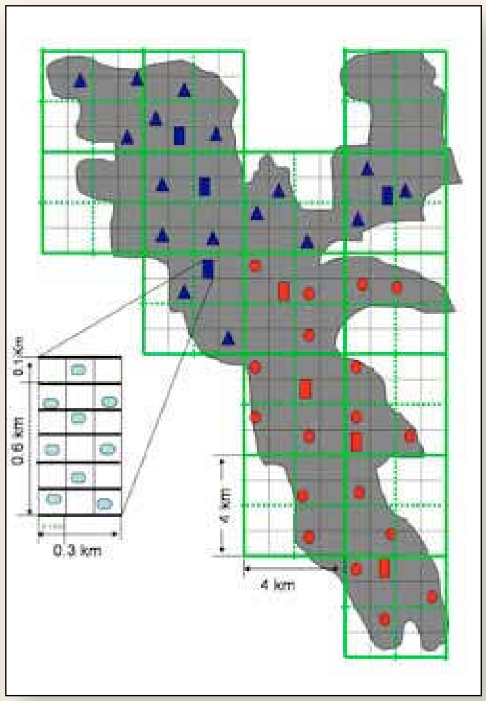


Figure 2. Sampling design in a hypothetical area classified as having good and poor habitat quality. The shaded area shows good quality habitat. Sampling cell size is 16 km². Circles and triangles show the position of camera trapping stations. The first sampling period is shown in red; the second one is shown in blue. The area where prey were sampled is highlighted.

taneous to that of the jaguar, but it will last for 10 days –the time it takes a paca to move or change its home range (Beck-King *et al.*, 1999).

All the camera trap stations should be placed in one day, and at least one sampling cell should be completed every day, especially in areas far from the base camp. This will depend on the habitat and the accessibility of the area. The size of the sampled area will be 0.2 km^2 for small species such as Central American agoutis (*Dasyprocta punctata*); this is the average minimum home range for this kind of species (Beck-King *et al.*, 1999; Chew and Chew, 1970). The sampling area will be divided into sampling cells of a size equal to or smaller than the minimum home range of an adult female or a group of animals, 0.2 km^2 in this case (Figure 2).

Each sampling cell will contain 9 sampling stations 100 to 300 m apart, covering an area of 20,000 m^2 (0.2 km^2; Figure 2). A 1 km^2 grid will be divided into 20 cells measuring 100 x 100 m, 9 of which will be used (600 x 300 m). Each sampling station is considered to cover 100 m^2. Places with the greatest probabilities of photographing prey species should be selected, and places with lesser chances of photographing animals should be avoided. The number of sampling stations should be limited through expert sampling, selecting areas with the most homogeneous vegetation patches. Using more stations and covering a broader area would probably result in recording different groups or populations for some species. Several camera trap studies have calculated frequency of occurrence or density for all prey species, without considering key aspects such as prey species' home ranges, habitat use patterns or size (e.g., Souza *et al.*, 2007; Srbek-Araujo and García, 2005). Besides, the sampling has usually been focused on potential prey weighing more than one kilo (Oliveira, 2002).

Two sampling cells should be used for each vegetation type; in the case of the jaguar, at least eight sampling cells are necessary. All the stations must be equipped with one camera, so at least 18 cameras and 8 sampling cells are necessary to assess the relative abundance of prey species.

Final considerations

The shape of the sampling area will depend on habitat quality, topography, and location of tracks, rivers and trails used to access the area. The trapping area should have the smallest perimeter possible. The size of the sampling area will depend on the location, ease of access to place and check the cameras, the number of cameras available and jaguar density in the area. The minimum trapping area suggested is 64 km^2, with cell sizes ranging from 9 km^2 for areas with dense vegetation or a high jaguar density (e.g., tropical areas) to 16 km^2 in open areas (e.g., xeric scrub) or areas with a low jaguar density.

Possible examples of shape and approximate location of traps in a sampling area are described next. Once a sufficiently large and accessible area has been selected, possible camera trap locations can be selected on a map to ensure there are no large gaps. Locations can be georeference and marked on a map to achieve the best possible distribution by selecting some of them. In some cases, it is necessary to open trails to access areas where there are gaps with no cameras. These trails should be opened as early as possible so that the animals become accustomed to using them (Figure 1).

Acknowledgments

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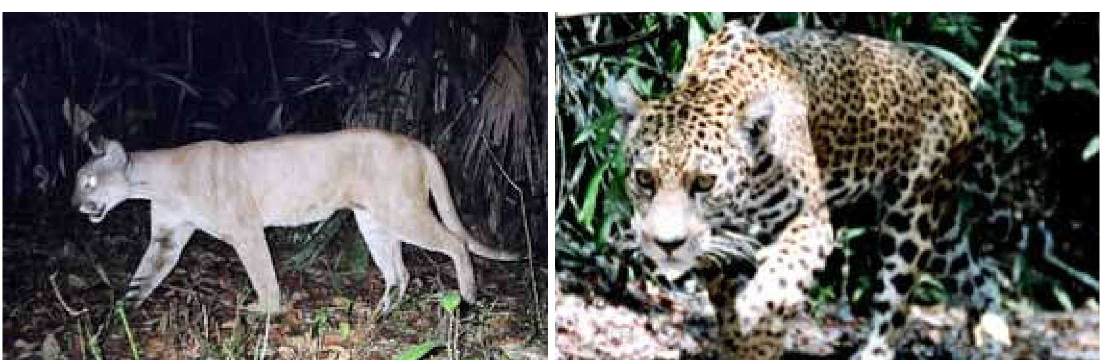

Species photographed using the sampling design for tropical forests.

CAMERA TRAPPING AS A TOOL TO STUDY JAGUARS AND OTHER MAMMALS IN THE LACANDON FOREST, CHIAPAS

Danae Azuara and Rodrigo A. Medellín

Resumen

La Selva Lacandona es una región prioritaria para la conservación de la biodiversidad en México. Por ello, es necesaria información sobre su estado de conservación y el seguimiento de poblaciones de especies sombrilla, como el jaguar. Con el trampeo fotográfico se puede obtener información sobre presencia y abundancia de distintas especies. Éste puede utilizarse como una herramienta importante para documentar el estado de conservación del bosque y afinar las decisiones de manejo y protección. El principal objetivo de este estudio fue diseñar un método de seguimiento para las poblaciones de mamíferos mayores de la Lacandona, particularmente del jaguar y sus presas. Se muestreó un área aproximada de 25 km^2, utilizando entre 24 y 28 sitios de trampeo activos por ocho semanas (las últimas dos utilizando atrayentes olfativos) tanto en la temporada lluviosa como la seca. No se encontraron diferencias en las abundancias de mamíferos para ambas temporadas, ni con el uso del atrayente olfativo. Se reconocieron individualmente la mayoría de los felinos (1 jaguarundi, 5-6 tigrillos, 4 jaguares, 4 pumas y de 13 a 18 ocelotes). El fototrampeo resultó útil para estudiar la presencia y abundancia de mamíferos terrestres mayores en las condiciones de la Lacandona, particularmente de mamíferos difíciles de estudiar como los felinos y así, dar seguimiento a las poblaciones en esta área y compararlas con otras. En el caso del jaguar y puma, es necesaria una mayor área de muestreo y distancia entre trampas-cámara, para fotografiar un mayor número de individuos y estimar su abundancia.

Palabras clave: abundancia, foto trampeo, especies presa.

Abstract

The Lacandon forest is a biodiversity conservation priority in Mexico. Thus, information on its conservation status and monitoring of umbrella and flagship species, such as the jaguar, is needed..Camera trapping gives us information on presence and abundance of many species. It can be an important tool to document the conservation status of a forest and tune up management and protection decisions. The main objective of the study was to design a monitoring method for large mammal populations in the Lacandon forest, particularly for jaguar and prey species. Trapping area was approximately of 25 km^2, with 24 to 28 trap-

ping points active for eight weeks, (the last two using olfactory attractants), this for both, dry and rainy season. Relative abundance for diverse mammal species were obtained, with no differences found between the two seasons, nor with the use of olfactory attractants. Most cats were recognized individually (1 jaguarundi, 5-6 margays, 4 jaguars, 4 pumas and 13 to 18 ocelots). Camera trapping is useful to study presence and abundance of terrestrial large mammals in the Lacandon forest conditions; particularly of elusive ones like felides, and thus to monitor their populations in the area and compare them with others. A larger trapping area and distance between cameras is needed to capture more jaguars and pumas, in order to estimate their abundance and population densities.

Key words: abundance, camera trapping, prey species.

Introduction

The Lacandon Forest has been identified as a biodiversity conservation priority in Mexico (Ceballos *et al*., 1998; Mendoza and Dirzo, 1999). It is the area with the greatest local biodiversity of mammals in Mexico –it contains about 25% of its species in less than 1% of the surface of the country (Medellín, 1996). It also protects a higher proportion of endangered species than would be expected in a random sample given its size. Moreover, this forest contains populations of many species that do not occur anywhere else in Mexico (Medellín, 1994). Besides its enormous biological richness, the area also represents an invaluable cultural heritage.

In spite of its great importance, the Lacandon Forest faces a complex situation regarding the conservation of its natural resources. It has more species in some category of risk than would be expected by chance (Medellín, 1994). Deforestation has been massive and very rapid, less than 500,000 hectares of forest remain of its original 1.5 million hectares (Medellín, 1991; Mendoza and Dirzo, 1999). In less than 20 years (1974-1991), 23% of its original vegetation cover disappeared. The main causes of the loss, change and fragmentation of the forest include public and private development programs, such as the construction of roads, hydroelectric dams, and the development of industries and plantations, among others (Challenger, 1998; Conservation International, 2003; Semarnat-Conabio, 1995). Changes in land use are mainly aimed at obtaining cropland and pastures for livestock, which are later abandoned and colonized by secondary vegetation (Flores Villela and Gerez, 1994).

Recognition of the importance of the Lacandon Forest has led to the creation of several protected areas (e.g., Lacantun Biosphere Reserve, Montes Azules Biosphere Reserve , and others); however, crop and livestock farming take place within most protected areas, and very few of them have the necessary management plans, infrastructure and staff to guarantee the effectiveness of management and conservation activities (Flores-Villela and Gerez, 1994). Therefore, the fact that most of what is left of the Lacandon Forest is protected to a greater or lesser degree does not guarantee that it will continue to exist. To ensure real protection, it is necessary to establish plans and actions with guaranteed results and obtain information about the area's conservation status.

The presence and abundance of mammals can be used to determine the conservation status of the Lacandon Forest and assess conservation efforts objectively. It is best to use predators considered as keystone, umbrella or flagship species (Karanth *et al.*, 2002; Meffe and Carroll, 1997). This is one of the most urgent conservation actions that must be carried out in the area. If the jaguar and other large mammals maintain large populations in a region, their ecosystems can generally be considered to be in good shape. Forest vegetation may apparently be healthy, but the functioning and structure of "empty" forests where large animals have been hunted suffer serious, long-lasting, and profound disturbances (Redford, 1992). The absence of certain animal species has an impact on the reproduction, survival and mortality of many plant and animal species (Challenger, 1998; Dirzo and Mendoza, 2002; Meffe and Carroll, 1997; Redford, 1992).

Camera trapping consists of using photographic cameras that are triggered by animal movement. This tool has been used to study organisms as diverse as birds in their nests (Laurance and Grant, 1994), medium-sized carnivores (Kerry, 1998), black bears (Morazzi *et al.*, 2002), and rhinos (Griffiths and Van Schaik, 1993). This method is particularly useful to study species whose abundance is naturally low and are cryptic or elusive (Morazzi *et al.*, 2002). Many studies that include camera trapping deal with species whose individuals have unique coat patterns (e.g., tigers), which makes it possible to study aspects such as population size and density. (Carbone *et al.*, 2001).

The use of camera traps has several advantages: few people are necessary to cover large areas and obtain a great deal of data; the necessary expertise and capacity to obtain quality data can be acquired in a short time, unlike the know-how needed to study animal signs; the method does not involve direct handling of animals and is therefore non-invasive; and the researcher does not need to be continually present in the study area, which minimizes changes in the natural behavior of animals (Azuara, 2005; Chávez and Ceballos, 2006; Karanth and Nichols, 2002).

Camera trapping studies provide information about presence and abundance, including relative abundance, minimum number known alive, and estimates of absolute abundance (Karanth *et al.*, 2002; Lynam, 2002). An important factor in any study using this tool is to measure camera trapping effort. This is done by measuring the number of active traps in a given amount of time (e.g., trap days). Comparable capture rates are obtained by standardizing the data per unit effort (Gompper, 2006; Karanth *et al.*, 2002). The urgent need to generate useful information to guide conservation decisions in the Lacandon Forest and other tropical rainforest areas in Mexico led to designing and testing a method to monitor populations of large mammals, and study trends in their abundance over time. This information is an essential element for the management and conservation of the protected area and its surroundings.

Study area

The study was carried out in the southernmost part of Montes Azules Biosphere Reserve. The area is located north of Ejido Playón de la Gloria (municipality of Marqués de Comillas) and delimited by the Lacantún River to the south east and east. Part of the western area is in Cerro Xanabcu, with an elevation of 440 masl (Figure 1). The study area includes many streams, which flow in the wet season but only have stagnant water in their lower stretches or no water at all in the dry season.

Methods

To carry out this study, we modified the method proposed by Lynam (2002) to study tigers in Indochina. He suggested a sampling area of 100 km^2 and a trap density of one trap/2 km^2. We used a sampling area of approximately 25 km^2 and a higher trap density. A total of 24 camera stations were placed in six lines, each of which was 5 km long, one kilometer apart. Four camera stations were placed in each line. Two cameras were placed in some stations (called check points by Lynam, 2002), to photograph both flanks of individuals and facilitate their identification. Systematic sampling was used, with a density of 0.8 camera traps/km^2 (Figure 2).

Besides systematic sampling with 24 stations, we used expert sampling (Lynam, 2002), placing two additional double camera stations in different points of a trail along the Lacantún river that is often used by various animals, particularly several

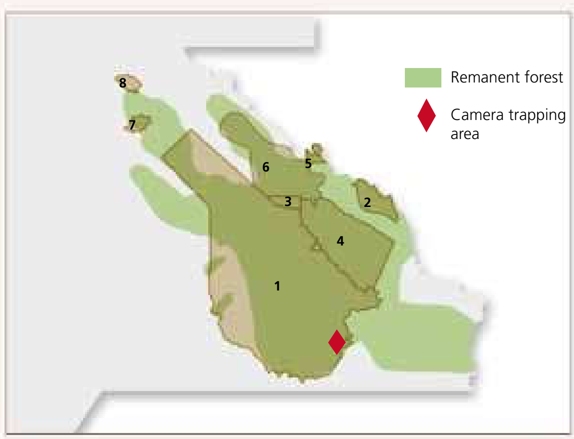

Figure 1. Protected areas in the Lacandon Forest:
1. Montes Azules
2. Chan-Kin
3. Bonampak
4. Lacantún
5. Yaxchilán
6. Sierra la Cojolita
7. Nahá
8. Metzabok

jaguars (observations of field assistants and information provided by local people). These stations were regularly moved to different places to prevent them from being stolen. The objective of the additional camera stations was to take photographs of both flanks of jaguars and other species, to contribute to the individual identification of animals captured in the 24 stations of the systematic sampling.

The 24 camera stations were active 24 hours a day for six weeks. As a complement, olfactory attractants were placed for two additional weeks in half of the traps (two of the four traps in each line, randomly chosen). This sampling effort was made in the wet season (September to November 2001) and the dry season (March to May 2002), amounting to a total of 1,344 trap days for each season. While the sampling lines were being installed, we ran a camera trapping test with only two camera traps from May to June 2001, obtaining data from 72 trap days.

To select the location of the four stations in each line, we chose places that were 800-1500 m apart and that were most likely to be visited by large mammals such as felids, artiodactyls or tapirs. Camera stations should be evenly distributed, avoiding large gaps without cameras where animals can move about with very few chances of being photographed.

The photographs obtained were used to develop a database for each season, with the following information: roll number, photograph number, location (line number and camera trap site number), date (month and day), time, use of attractant or not,

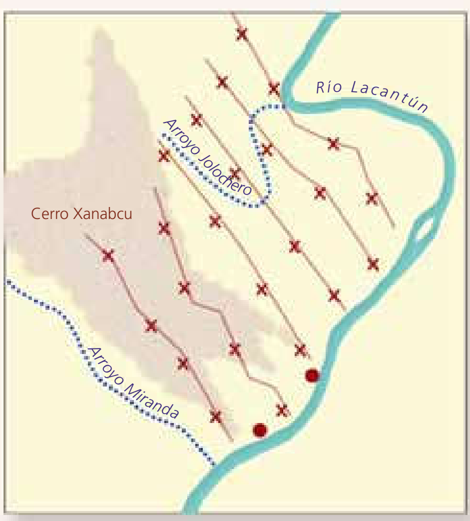

Figura 2. Camera trapping grid showing the arrangement of the lines and trapping sites in the study area.

✕ Sites where the camera traps were placed for 8 weeks

● Additional trapping sites (short periods) species photographed, number of individuals, number of individuals in different categories (adult males, adult females, adults, juveniles) and observations. Consecutive photographs (with a minimum interval of 3 minutes between pictures) of the same species were considered as just one capture. These data were used to calculate the standardized capture rate per effort unit for each species, expressed as number of captures in 1,000 trap days.

To test whether some of the differences between both seasons were significant or not, we ran unpaired and two-tailed t-tests comparing capture rates in different sites for each species. We calculated capture rates for some species in each of the 24 fixed camera trapping sites (N = 24, gl =23). These tests were only conducted in species with high capture rates.

To test the effectiveness of olfactory attractants at increasing the capture rates of felids, we also ran t-tests to compare capture rates at weeks 7 and 8 between traps with olfactory attractants and traps without them (N = 6, gl = 5). Capture rates were also compared between weeks 5 and 6 (without olfactory attractants) and weeks 7 and 8 (attractants in half of the stations). Data for all species of felids were combined in both cases to make the comparison more robust.

As regards felids, individuals were identified thanks to their coat patterns and scars. The minimum number of individuals known to be alive in an area (MNKA) was obtained by adding up all the individuals that were known to be present in a given capture session. It is possible that not all the animals present in the area were captured.

Results and discussion

Capture rates (relative abundance indices) of felids are shown in Table 1. Table 2 shows the number of individuals recognized. The same number of pumas and jaguars was identified in the area throughout the year, but there was a higher number of puma captures, so the puma's relative abundance index is greater than the jaguar's (Table 1).

The camera traps recorded 14 species of carnivores and ungulates, including 5 species of felids (Table 1). Only five species of medium to large sized mammal occurring in the area were not photographed: southern river otter (*Lontra longicaudis*), raccoon (*Procyon lotor*), howler monkey (*Alouatta pigra*), spider monkey (*Ateles geoffroyi*), and kinkajou (*Potos flavus*). The first two species are associated to bodies of water and the last three live in trees, which makes them difficult to capture in this sampling design. Other species photographed included marsupials of the family Didelphidae, large and small rodents, armadillos, rabbits, and several species of birds. Many of these species are potential prey for jaguars (Figure 3, Table 3). The species with the highest capture rates were pacas, armadillos, tapirs, brocket deer, collared peccaries, coatis and white-lipped peccaries. These capture rates can be used as relative abundance indices to monitor trends over time. There were more captures of collared peccaries than white-lipped peccaries, but the latter appeared in more photographs in the sampling period because they form larger groups (Table 4; e.g., Cuellar *et al.*, 2003).

The capture rates in the two seasons studied were similar for all the species (Table 5). No differences were found either between photographs of felids obtained by camera traps with olfactory attractants and cameras without attractants (Wet $t = 0.36$; Dry $t = 0.16$; $p > 0.05$) or between each of the seasons (Wet $t = 0.07$; Dry $t = 0.29$; $p > 0.05$). However, felid captures in traps with attractants included a greater number of photographs than those without attractants, which seems to suggest that

Table 1. Relative abundance indices of felid species

	Wet			Dry		
Species	**# F**	**# C**	**C/1,000**	**# F**	**# C**	**C/1,000**
L. pardalis	21	16	13.25	21	17	13.34
P. concolor	15	8	6.62	10	7	5.7
L. wiedii	3	3	2.48	3	3	2.35
P. onca	3	2	1.65	9	6	4.71
P. yaguaroundi	3	1	0.83	0	0	0

F = number of photos taken, # C = number of captures, C/1,000 = d-t relative abundance index, captures standardized to an effort of 1,000 trap days.

Table 2. Number of different individuals recorded per felid species

	test	**wet**	**dry**	**throughout the year**
P. yaguaroundi	1	0	0	1
L. wiedii		2-3	3	5 - 6 (3♂, 2 -3 NI)
P. onca	1	1	2	4 (2♂, 1♀, 1 NI)
P. concolor		3	3	4 (2♂, 2 NI)
L. pardalis	1	8	10-13	13 - 18 (5♂, 7♀, 1 - 5 NI)
+ 1 cría				

Where ♂ represents males, ♀ represents females, and NI represents individuals whose sex was not identified.

Table 3. Relative abundance indices of most captured prey and potential jaguar prey

	Wet			Dry		
Species	**# F**	**# C**	**C/1,000**	**# F**	**# C**	**C/1,000**
C. paca	75	62	51.32	29	25	19.62
D. novemcinctus	52	49	40.56	17	17	13.34
T. bairdii	49	25	20.7	118	45	35.32
M. temama	31	24	19.87	20	15	11.77
T. tajacu	37	19	15.73	55	26	20.41
N. narica	20	16	13.25	16	12	9.42
T. pecari	48	13	10.76	71	22	17.27

F = number of photos taken, # C = number of captures, C/1,000 = d-t relative abundance index, captures standardized to an effort of 1,000 trap days.

Figura 3. A few of the species recorded in this study. From left to right and top to bottom, margay (*Leopardus wiedii*), paca (*Agouti paca*), tapir (*Tapirus bairdii*), ocelot (*Leopardus pardalis*), white-lipped peccary (*Tayassu pecari*), red brocket deer (*Mazama temama*), jaguar (*Panthera onca*), puma (*Puma concolor*) and armadillo (*Dasypus novemcintus*). Note the botfly larvae markings on the skin of the puma.

the attractant may have had only a marginal influence on the behavior of these species.

The results agree with studies that show that camera traps are a useful tool to document the presence and some general demographic parameters of large mammal species in tropical rainforests (e.g., Maffei *et al.*, this volume). Capture rates of large mammals such as deer, peccaries, jaguars, pumas, tapirs and ocelots can be used as relative abundance indices to monitor their populations and make comparisons with other areas (Maffei *et al.*, 2002).

It is important to define the target species in a camera trapping survey beforehand to choose the most suitable sampling type and design (Karanth and Nichols, 2002). For example, the use of camera traps is not recommended for documenting mammals weighing less than 2 kg, as they are too small to be detected by the trap sensors. There are many different camera traps available on the market with a broad range of mechanisms and functions (Medellín *et al.*, 2006). Our recommendation is to assess their characteristics, such as the type of media (digital or film), the type and quality of the camera, whether it is water, cold or heat resistant, the animal detecting mechanism, battery life and, of course, price and availability of spare parts or service.

The greatest sample size was obtained for ocelots. Among species whose individuals were recognized, ocelots showed the highest number of captures and recaptures (Figure 4). The distance between traps and size of the camera trapping area were appropriate to study this felid (Cuellar *et al.*, 2003). In the case of jaguars and

Table 4. Index of group size of collared and white-lipped peccaries

Species	Average No. of photos	Size of groups observed
T. tajacu	1.8	1 to 4 individuals
T. pecari	3.5	20 a 50 individuals

toThe average number of consecutive photographs of groups of peccaries taken in a capture event potentially reflects group size.

Table 5. Seasonal abundances of mammals in the Lacandon Forest, Chiapas, Mexico

Species	t calculated
A. paca	0.18754
D. novemcinctus	0.17425
N. narica	0.87362
M. temama	0.59509
T. bairdii	0.20599
T. tajacu	0.64554
T. pecari	0.85772
L. pardalis	0.65881

None were significant at a $\alpha = 0.05$; t-tables = 2.07

pumas, a greater distance between cameras and larger camera trapping areas would be advisable to increase the chances of capturing a greater number of individuals, given the broad movements of these species (Chávez and Ceballos, 2005).

Perspectives

It is clear that camera trap protocols and reviews of studies obtained with these tools will continue to be published. Studies involving camera trapping have become a highly important instrument for the conservation of large mammal species, and decision-making towards this objective is now more robust. We must continue to make progress in this respect, strengthening protocols and improving data collection, analysis, interpretation, implementation and instrumentation for decision makers.

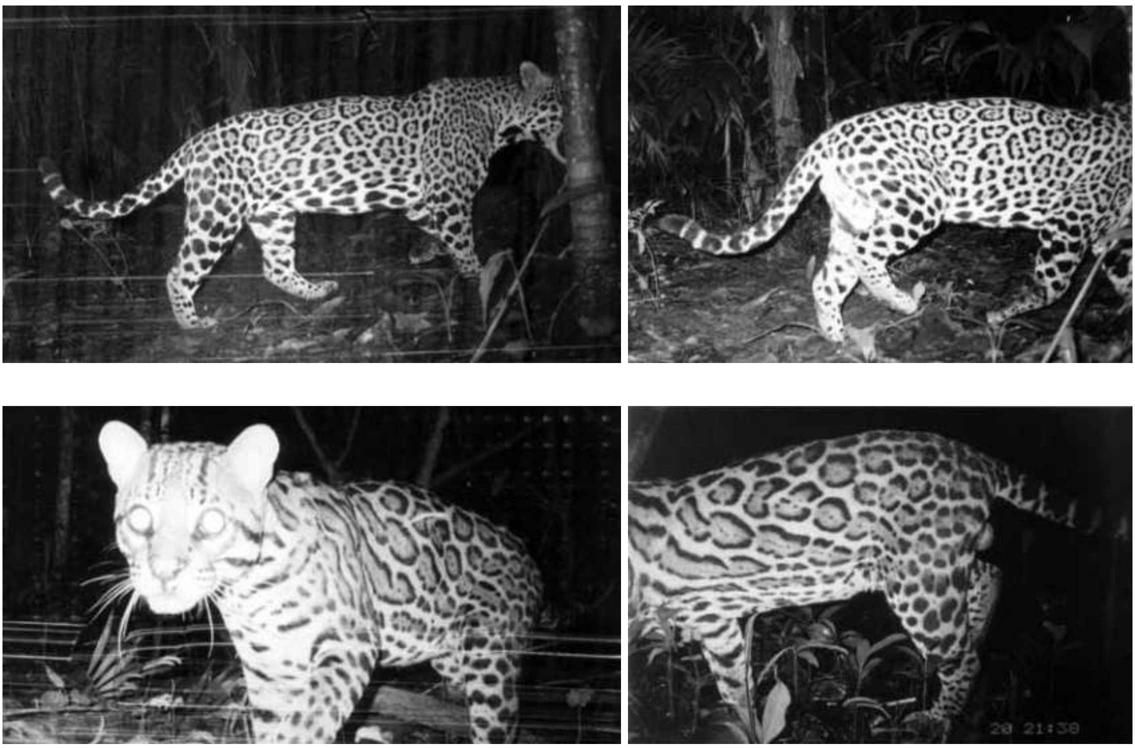

Figure 4. A few of the photographs of felids used for recognition of individuals by comparing the shape and location of their rosettes. Top: two captures of the same male jaguar; bottom: two captures of the same male ocelot.

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ESTIMATING JAGUAR POPULATIONS USING CAMERA TRAPS: AN EXAMPLE IN BOLIVIA

Leonardo Maffei, Erika Cuéllar, and Andrew Noss

Resumen
En este estudio se reportan los resultados de los esfuerzos para capturar jaguares con trampas cámara en el bosque seco del Parque Nacional Kaa Iya del Gran Chaco, es Bolivia. Se adaptó la metodología sistemática que fue desarrollada por primera vez en la India para censar tigres (*Panthera tigris*) basada en la identificación de individuos a través del patrón de manchas en el pelaje. Se estimó la abundancia usando análisis estadísticos de captura y recaptura en un área estimada a partir de la distancia máxima en que se mueven los jaguares. Esta metodología resultó ser exitosa para la estimación de densidad de jaguares en el Kaa Iya. La densidad poblacional se estimó en un individuo/20 km^2 y un individuo/30-45 km^2 en los dos sistemas de paisaje más extensos del área.

Palabras clave: trampas-camara, densidad poblacional, jaguar, Bolivia

Abstract
This paper reports on efforts to camera trap jaguars in the dry forests of the Kaa-Iya del Gran Chaco National Park in Bolivia. The authors adapted systematic methodologies first developed to survey tigers in India, based on individually distinctive pelage patterns. Abundance was estimated using capture-recapture statistical analysis, and a sample area defined based on the maximum distance that individual jaguars move during the sample period. The methodology has proved successful for jaguars in dry Chaco forest: population densities of 1/30–45 km^2 and 1/20 km^2 are estimated in the two most extensive landscape systems of Kaa-Iya.

Key words: camera-traps, population density, jaguar, Bolivia

Introduction
The jaguar (*Panthera onca*) is the largest felid in the Western Hemisphere. It is an important figure for many indigenous cultures, tourists and hunters, but it is usually considered a threat to livestock farming (Hoogesteijn *et al*., 1993; Hoogesteijn, 2001; Medellín *et al*., 2002; Rabinowitz, 1986).

The Kaa Iya National Park was created in Bolivia in 1995 to maintain and protect large populations of endangered species that require extensive ranges, such as the white-lipped peccary (*Tayassu pecari*) and the jaguar (Taber *et al.*, 1997). The park contains a considerable jaguar population that was only discovered recently. The only studies on the species conducted in the area are preliminary studies based on tracks or scats (Cuéllar, 1997; Maffei, 1995).

The objective of this study was to assess jaguar population density in the Kaa Iya National Park.

Study area and methods

The Kaa Iya National Park covers 34,400 km^2; most of the area by dry forest, with three main landscape systems: Chaco transitional forest, Chaco alluvial plain forest and Chiquitano transitional forest. The first two types of forest have dense, thorny vegetation with a low canopy (4-8 m) and emergant trees up to 15-20 m high; while Chiquitano transitional forest has a slightly higher canopy, between 8 and 20 m high (Navarro and Fuentes, 1999). Average temperature is 25-26°C, the dry season lasts 4 to 6 months, and annual rainfall ranges between 450 and 750 mm.

Sampling took place from 2002 to 2004 in three sites where research camps already exist. The camps are located in the Chiquitano transitional forest and Chaco alluvial plain forest; the distance between them is about 100 km (Figure 1). Between 24 and 32 pairs of camera traps were placed in each research area for a minimum of two years. Cameras were placed 1-2 km apart on dirt tracks suitable for vehicles and trails that were specifically opened for this purpose; the goal was to form a polygon

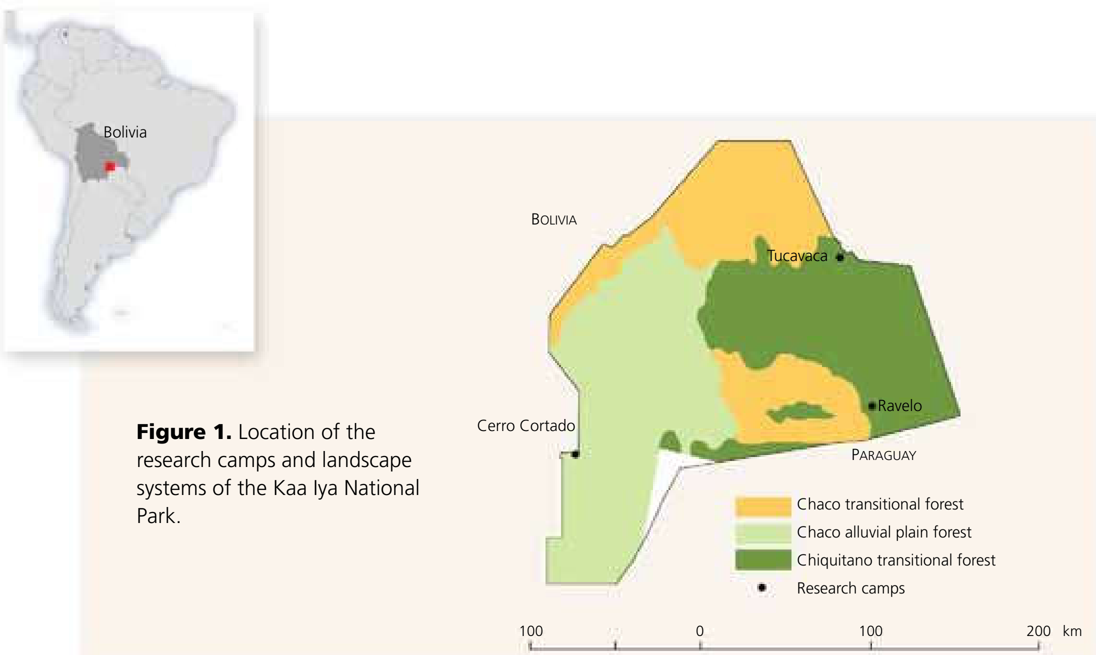

Figure 1. Location of the research camps and landscape systems of the Kaa Iya National Park.

covering at least 50 km² (Silver, 2004). Additional traps were placed next to water holes to increase the chances of photographing individuals.

Individual jaguars were identified by their unique coat patterns, as happens with other spotted cats (Karanth, 1995). Prior sampling showed that jaguars are active day and night, so the cameras were programmed to be active 24 hours a day. They were always placed in pairs, because the coat pattern is different on either flank of the animals. Sampling always lasted 60 days so as not to violate the closed population assumption.

Data obtained were introduced into a presence/absence matrix where columns represented days of capture effort and rows represented individuals. The data were analyzed with the CAPTURE program to obtain abundance (Rexstad and Burnham, 1991). The area of influence of the camera traps, used to calculate the area sampled, was calculated by applying to each camera trap a buffer equivalent to half the average of the maximum distance traveled by each animal photographed by at least two different stations (Figure 2). In turn, he CAPTURE and sample area data were used to estimate jaguar population density/100 km².

Results

Most jaguar photographs were obtained in dirt tracks or trails. Four to seven individuals were recorded in each site, and the size of the sampling areas was 128-309 km². The sex ratio of jaguars photographed was 1:1, usually three males and three

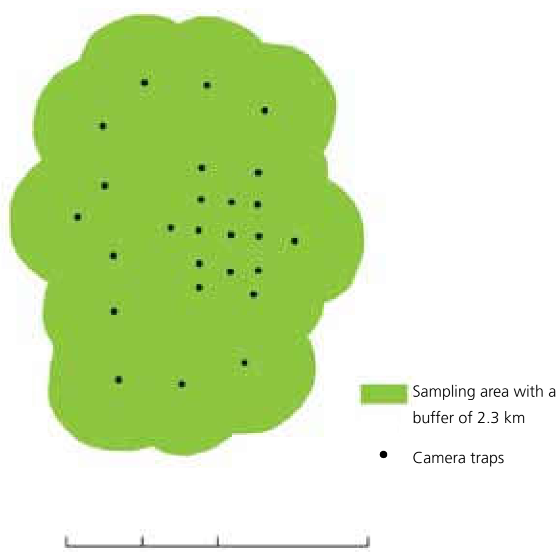

Figure 2. Example of a sampling area: a buffer equivalent to half of the maximum distance traveled by each animal photographed by at least two different stations was applied to each camera trap.

females. Based on 121 records obtained in the three sites, jaguars were active at any time of the day, but showed two activity peaks: one between 03:00 and 08:00 hr, and one between 15:00 and 22:00 hr (Figure 3).

Maximum distances traveled by each animal photographed in the same sampling exercise ranged from 1.9 to 16.5 km (mean = 6.4 km). The minimum observed range recorded for four females was 29, 20, 10 and 24 km² (x = 20,7; sd = 8). Three males photographed had larger minimum observed ranges –65,44 and 24 km² (x = 44.3; sd = 20.5). In one of the sampling sites, the observed range of a male completely overlapped those of two females. Significant differences were found between males and females (t = 0.17)

Population densities ranged from 1.57 to 5.37 individuals/100 km². Although density was as much as three times greater in some sites than others, jaguar density was similar in the two sampling exercises carried out in each site (Table 1).

The data obtained have led to the following estimates: the Chiquitano transitional forest, which covers 33% of the Kaa Iya area, (11,500 km²), contains one jaguar/30-45 km². The Chaco alluvial plain forest, which covers 40% of the area (13,800 km²), has a density of one jaguar/20 km². The remaining dominant landscapes of the park cover about 9,100 km² and have not been sampled yet. However, considering that rainfall and vegetation are intermediate compared to the other two landscape systems, we may assume intermediate jaguar densities between both landscapes, with at least one jaguar/45 km², and a total estimate of about 200 individuals. Adding up all the densities, Kaa Iya National Park is estimated to have a population of 1,000 individuals.

Each photograph records the time when it was taken, which led to the conclusion that the jaguar can be active 24 hours a day but shows an activity peak between 03:00 and 08:00 hr and 15:00 and 22:00 hr. Its activity decreases in the hottest hours of the day and around midnight. Four other felid species are sympatric with jaguars

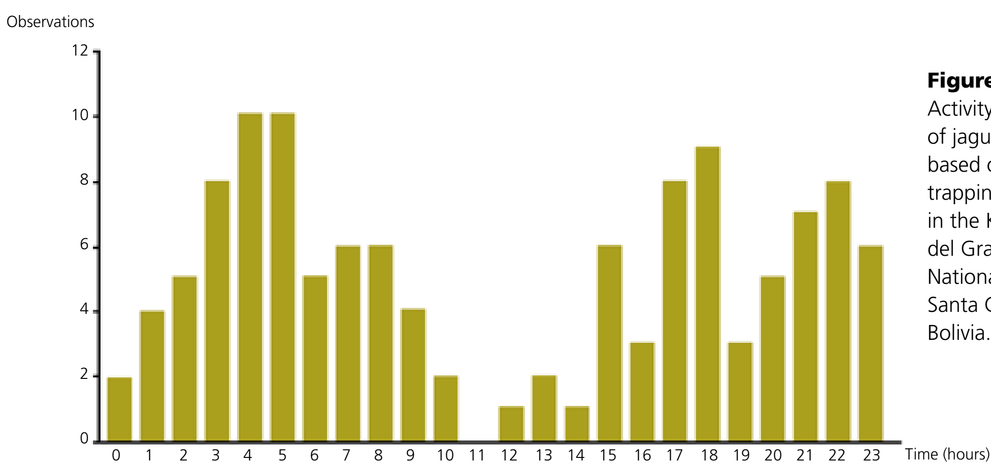

Figure 3. Activity pattern of jaguars, based on camera trapping studies in the Kaa Iya del Gran Chaco National Park, Santa Cruz, Bolivia.

in our sampling areas: the puma (*Puma concolor*), ocelot (*Leopardus pardalis*), Geoffroy's cat (*Leopardus geoffroyi*) and jaguarundi (*Puma yagouaroundi*). Tests using the same capture-recapture methodology with camera traps suggest puma densities of 2.9 to 7.2 ind./km^2 (Kelly *et al.* 2008), similar to or slightly higher than that of jaguars; ocelots (25 to 67 ind./100 km^2) are much more abundant (Maffei *et al.*, 2005). We obtained too few photographs of Geoffroy's cats and jaguarundis to be able to estimate their density (Cuéllar *et al.*, 2003; Maffei *et al.*, 2002;).

Discussion

Many factors contribute to confusing the relation between capture frequency and density in different sites and between species: the species' movement patterns, location and efficiency of camera traps, availability and condition of roads and trails, climate and season. In many samples, however, density is correlated with the number of photographs, so capture frequency can be considered as a relative abundance index (Carbone *et al.*, 2001). Yet, it is important to note that, even in systematic sampling, capture frequency is not always a reliable indication of density (Jennelle *et al.*, 2002).

Although there are other methods to identify jaguar individuals (e.g., tracks and DNA analysis of scats), sampling with camera traps is the only statistically robust methodology available to estimate jaguar populations densitie. It is an expensive method, considering the costs and the number of camera traps, rolls and batteries needed, as well as the investment it takes to open trails when there are no rivers or trails available. However, it may be more practical than radio telemetry, which is more costly in terms of capture effort, equipment (radio-collars) and data collection (e.g., airplane flights). One of the problems of radio-telemetry is that it is invasive and therefore implies a risk for researchers and animals; besides, at least one year of data collecting is necessary to calculate home ranges. Camera trapping is a non-invasive method that provides statistically robust density estimates after only two or three months (Karanth and Nichols, 1998).

Table 1. Jaguar population density estimates in the Kaa Iya National Park, Bolivia

	Captures/1,000 trap nights	Abundance	Effective area (km)	Area (km^2)	Density	Standard Deviation
Tucavaca I	12.5	7	3.00	272	2.5	±0.77
Tucavaca II	7.8	4	2.30	128	3.1	±0.97
Cerro Cortado I	10.1	7	2.41	137	5.1	±2.10
Cerro Cortado II	19.9	8	2.81	149	5.3	±1.79
Ravelo I	9.7	7	3.94	309	2.2	±0.89
Ravelo II	15.1	5	4.10	319	1.5	±1.16

Jaguar density in Kaa Iya is lower than estimates obtained in more humid forest areas such as Belize (7.5-8.8 ind./100 km^2), but it is similar to that of San Miguelito private reserve in the Chiquitano forest in Bolivia (4.2 ind/100 km^2) (Rumiz *et al.*, 2003; Silver *et al.*, 2004).

Jaguars showed activity peaks at dawn and dusk, which agrees with the findings of Rabinowitz and Nottingham (1986). This behavior is probably related to the activity of some of its main prey, such as the brown brocket deer (*Mazama gouazoubira*) and the collared peccary (*Tayassu tajacu*). These species are more active at dawn and dusk (Barrientos and Maffei, 2000; Miserendino, 2002).

It has been suggested that a population must have 500 to 650 individuals to be viable (Eizirik, 2002; Franklin, 1980; Redford and Robinson, 1991). However, this kind of parameter has not been estimated in jaguars. In spite of the low jaguar density in the Chaco, and given the huge size of Kaa Iya National Park and its good protection measures, the jaguar is above the minimum viable population level. Therefore, it can be concluded that this population is guaranteed to remain for at least 100 years.

Recommendations

This study showed that the Kaa Iya National Park is one of the protected areas with the largest estimated jaguar populations due to mainly because its size. However, to complete data on density, our main recommendation is to sample the third dominating landscape system in the park to obtain data on jaguar density in this area and avoid extrapolating data from neighboring landscape systems.

Acknowledgments

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HEALTH ASSESSMENT OF WILD JAGUAR POPULATIONS AS A CONSERVATION STRATEGY

Dulce M. Brousset and Alonso A. Aguirre

Resumen

Existe un creciente interés de determinar cuáles son los efectos que las infecciones y enfermedades tienen sobre las poblaciones silvestres, siendo muy poco conocidas en los felinos silvestres y para el jaguar en México, prácticamente no existen datos publicados. Cuando el hábitat natural se fragmenta, disminuyen las poblaciones de las especies, aumentando las interacciones con animales domésticos y el contacto con patógenos potenciales. Estos procesos incrementan el riesgo potencial de adquirir enfermedades por los individuos, por la introducción de enfermedades exóticas y la presencia de enfermedades emergentes. Se propone adoptar un plan estándar para la evaluación de salud de las poblaciones de jaguares silvestres en México, para que sea utilizado en todos los proyectos de campo. Esto permitirá comparar los resultados obtenidos a lo largo del tiempo en diferentes sitios, por diferentes grupos de investigadores, y generar conocimientos clínicos y ecológicos sobre el papel de los patógenos y enfermedades en la dinámica de las poblaciones. Además permitirá identificar aquellas enfermedades que sean amenazas directas o indirectas para la conservación de la especie y, a partir de los hallazgos de las evaluaciones generales de salud, se podrán hacer recomendaciones para el manejo y conservación del jaguar a largo plazo.

Palabras clave: enfermedades infecciosas, patógenos, salud animal.

Abstract

There is a growing interest to determine the effects of infectious disease in wildlife populations. The effects are little known for wild felids, and for the Jaguar in particular there is no published information. As the natural habitat fragments, wild populations tend to decline, and domestic-animal wildlife interactions increase, leading to a major exposure to potential pathogens in wild populations. In addition, there is the potential threat of emerging infectious diseases and exotic disease introductions. We propose to implement a standard protocol for the health evaluation of wild jaguar populations in Mexico. This protocol can be used in all field related activities of jaguar conservation. A standard protocol for health evaluation will allow different jaguar researchers to compare results from different areas over time and produce clinical and ecological knowledge on the role of infectious diseases and other pathogens on the population dynamics of the species. Also, this standardization will allow us to identify diseases that may represent a direct or indirect threat to jaguar conservation. Based on future health assessments, we will be able to develop strategic rec-

ommendations to strengthen our understanding of the ecoepidemiology and conservation of jaguars in Mexico.

Key words: animal health, epidemiology, pathogens, wildlife diseases.

Introduction

One of the most important causes of decline in populations of mammals –especially large felids– is habitat fragmentation, which has direct and indirect negative effects on their populations (Deem *et al.*, 2001; Saunders *et al.*, 1991). According to current ecological and epidemiological theories, native mammal species in reduced, fragmented and isolated habitats are more likely to interact with invasive species and infectious diseases (Holmes, 1996). Some infectious diseases have devastating effects on wildlife, especially when they involve foreign agents that the population has not coevolved or developed an immunological memory against them (Goodman and Buehler, 1996).

Conservation medicine is the link between the fields of human, animal and ecosystem health, and brings together the knowledge of these disciplines. The identification of new medical problems associated to environmental change such as climate change, pollution, market globalization and the increase of human activities in wildlife habitats has led to the development of this discipline (Patz *et al.*, 2004). Conservation medicine provides information to identify pathogens involved in emerging diseases and has proposed new strategies to assess them systematically and periodically at different levels in space and time (Aguirre *et al.*, 2002; Tabor *et al.*, 2001).

Conserving the health of wild animal populations should be a key part of ecosystem health. Viable animal populations are essential for the functioning of ecosystems and imply healthy animals. To assess the health of wild animals in the ecosystem, it is necessary to know about potential pathogens in the environment and the current prevalence of disease in the region. Ecosystem health can be assessed by dealing with endangered species, the most common native species, or sentinel species, that is, species whose health provides information about the overall health of the ecosystem (Aguirre *et al.*, 2002; Munson and Karesh, 2002).

The jaguar is an excellent sentinel species, as it can be used as an indicator of changes in space and time. It can be in contact with different pathogens and spread them in the food chain as it moves in and out of infected or contaminated areas. Besides, habitat fragmentation leads to greater interaction with cats, dogs, and other domestic animals, and a decrease in natural prey, which causes higher consumption of unusual prey or domestic animals. As a result, contact with potential pathogens increases (Aguirre and Tabor, 2004; Tabor and Aguirre, 2004).

We propose a protocol to assess the incidence of disease in wild felids and its impact on population dynamics.

Methods

There are few examples in the literature of infections or diseases that have caused a major decline in populations of wild felids. One of the most important and dramatic cases was the epizootic of canine distemper virus in lions. In 1994 and 1995, the outbreak of this viral disease affected 20-30% of the 3,000 lions of the Serengeti National Park, in Tanzania, and caused the death or disappearance of about 87 lions in a population of 250 (Roelke-Parker *et al.*, 1996). At first, it was believed to be a new disease of felids, because it had only caused epizootics in jackals, foxes (1987) and wild dogs (1991). The virus that was isolated from dead lions was very similar to that of domestic dogs in the area, and antibodies against the disease were found in 85% of the lion population. It was first considered to be an exotic disease for felids, and the social characteristics of lions were believed to have contributed to the spread of the infectious agent. However, a study carried out on several species of large felids kept in North American zoological collections found antibodies against the disease in several individuals (Appel *et al.*, 1994).

Although the jaguar's solitary behavior may reduce the risk of an epizootic caused by the spread of a contagious disease such as canine distemper or scabies, diseases that have caused health problems in African carnivores could also affect jaguars (Deem *et al.*, 2002).

In the case of wild American felids, there are records of the presence of a number of pathogens such as viral agents (calicivirus and coronavirus) in pumas in the United States (Roelke *et al.*, 1993); feline immunodeficiency virus in pumas and bobcats (Olmstead *et al.*, 1992); feline panleucopenia in Canadian lynx (McCord and Cardoza, 1982), bobcats and pumas (Roelke *et al.*, 1993); rhinotracheitis in bobcats and rabies in Canadian lynx (McCord and Cardoza, 1982), bobcats (Carey and Mc Lean, 1978) and pumas (Roelke *et al.*, 1993). Most studies have only assessed the presence of antibodies against a specific agent, without specifying the impact of the disease on population dynamics.

Regarding the health of wild jaguars, there are two records of the presence of gastrointestinal parasites (Patton *et al.*, 1986; Hoogesteijn and Mondolfi, 1992) and one record of ticks in Brazil (Cabruna *et al.*, 2005). In the case of other neotropical felids, only Deem *et al.* (2004) have published the results of serology on a free-ranging oncilla, also known as little spotted cat (*Leopardus tigrinus*) in Bolivia. The animal tested positive for antibodies against rabies and feline panleucopenia, and negative against canine distemper and several viral diseases of felids (calicivirus, herpesvirus, immunodeficiency, coronavirus and leukemia). Some studies have assessed the presence of endoparasites in ocelots and jaguarundis in Belize (Patton *et al.*, 1986), the oncilla in Bolivia (Deem *et al.*, 2004) and ocelots in Texas (Pence *et al.*, 2003). Regarding the presence of ectoparasites, there is only one report of notoedric mange (*Notoedres cati*) in an ocelot found dead in Texas (Pence *et al.*, 1995).

Most publications on health problems in jaguars refer to captive individuals in the United States. They include infectious diseases (viral, bacterial or parasitic), dental problems, trauma and neoplasms (Cirillo *et al.*, 1990; Fransen, 1973; Hope and Deent, 2004), serological evidence of infection with canine distemper virus and feline immunodeficiency (Appel *et al.*, 1994 ; Barr *et al.*, 1989; Brown *et al.*, 1993), and seroprevalence of trichinellosis (Yepez-Mulia *et al.*, 1996). There are a few reports on health problems in jaguars kept in zoos in Brazil (Silva *et al.*, 2001), and only one on animals kept in a zoo in Mexico (Yepez-Mulia *et al.*, 1996).

A comprehensive list of helminthiasis in terrestrial mammals was recently published. It includes jaguars, with potential clinical signs and pathological lesions (Aguirre and Guerrero, 2001).

There is evidently a serious lack of studies and publications on the health of wild jaguar populations, particularly in Mexico. It is urgent to generate information so that the dynamics of diseases and their impact can be understood.

We intend for the Epidemiological Protocol to be a working document that serves as a guide to biomedical research; the aim is to standardize procedures used in field projects, specifically those related to health and disease. The protocol can be used by veterinarians, biologists trained in biomedical science, disease specialists and epidemiologists. This long-term strategic plan will make it possible to assess the prevalence of diseases in the jaguar population, conduct retrospective analyses of samples or data previously collected, prospective studies, and even study the role of epidemiological techniques in translocation and rehabilitation efforts.

The Jaguar Health Program Manual of Jaguar Conservation Plan (JCP) established by the Wildlife Conservation Society (WCS) (Deem and Karesh, 2002) is currently available at the address <www.savethejaguar.com>. The manual was developed by veterinarians of the WCS field veterinary program (www.fieldvet.org) to provide a standardized, safe and ethical approach to capture, handling, and sampling protocols to ensure that Jaguar Health Program is carried out in a consistent fashion throughout the jaguar's range.

The main objectives of Jaguar Health Program are:

1. To provide standardized methods to assess the overall health status of jaguars in the wild.

2. To determine disease threats to jaguars including both direct threats (e.g., infectious diseases spread via domestic animals, prey, and other free-ranging felids) and indirect threats (e.g., habitat fragmentation and degradation that may increase disease risks).

3. To provide recommendations, based on findings from the health assessment, for the long-term management and conservation of jaguar.

The manual includes chapters on capture and immobilization, handling immobilized jaguars and anesthetic emergencies, post anesthetic recovery, animal sampling, data collection, analysis and distribution, as well as a list of figures, tables, appendices and bibliography.

Methods

Goal

To adopt and use a standard protocol in field projects aimed at assessing the health of wild jaguar populations in Mexico. This will contribute to the development of an epidemiological plan to identify priorities and implement projects, as an essential part of the research and recovery activities carried out by the federal government, non-governmental organizations (NGOs), universities and other groups. The final goal is to develop a long-term plan to reach the health-assessment objectives related to the management and recovery of species like jaguar (Brousset, 2005; Brousset *et al*., 2006). For example, this health monitoring plan will include relevant aspects regarding translocation of individuals and contingency plans for epizootic diseases, exposure to anthropogenic contamination or natural disasters. A component of the plan deals with health assessments already under way, as well as prospective assessments of potential risks to assess changes in health over time and determine effects on population abundance and reproductive success.

Specific objectives

1. To establish and create a database including "normal" parameters regarding the presence of pathogens and diseases in the different wild jaguar populations, to obtain results that explain their dynamics over time.

2. To identify the pathogens and diseases that must be assessed, the necessary biological samples, and techniques used in laboratory analysis.

3. To create a manual including the different techniques for obtaining and preserving biological samples, considering different fieldwork conditions (protocols for sampling, necropsy, clinical evaluation and anesthesia).

4. To identify laboratory tests available in Mexico and establish a network of recommended institutions or laboratories to assess the different biological samples.

5. To create a bank of biological samples that can be assessed in cases of emerging diseases or contingencies.

6. To carry out a retrospective analysis of previously collected biological material and include the results in the data bank.

7. To assess the health status and diseases of each jaguar so that changes in individuals and eventually populations can be identified over time. This will provide information about the role played by diseases as direct or indirect threats for jaguars.

8. To develop prevention and control strategies to mitigate the effects of suboptimal health status and contribute to recovery. To provide recommendations for the long-term management and conservation of the jaguar based on findings of health assessments.

9. To reduce the potential risk of future impacts on jaguar health by developing appropriate response plans to different contingencies.

Results and discussion

Diseases can be identified through the clinical or pathological assessment of individuals. This provides information to analyze trends in the population or the ecosystem. An effort must be made to seize every opportunity to obtain biological samples of any individual. This can be done by taking samples opportunistically in research projects and when handling wild animals (Carees and Cook, 1995). Blood, hair and scat samples can be obtained from animals anesthetized for any other purpose. Participation of veterinarians in such field projects has led to obtaining a greater amount of biomedical information through physical examination and selective sampling methods (Figure 1). If samples collected are not immediately tested in the laboratory, they can be preserved for future comparative studies by using suitable methods (e.g., freezing). This provides a baseline of "normal" parameters regarding the presence of pathogens and disease in the different wild populations of jaguars, and clarifies their dynamics over time, including multiple species and long-term studies (Munson and Karesh, 2002).

The overall health assessment of wild jaguars is particularly valuable in the potential case that mass mortality events could occur. Results of serology or parasitology tests after the outbreak of the disease can be compared with results obtained in the population before the disease and show the presence of new pathogens or an emerging or re-emerging disease. These essential comparisons cannot be made if the health of the population has not been previously assessed (Munson and Karesh, 2002).

Disease risk analyses are starting to be included in many environmental impact assessments for wildlife reintroduction or translocation programs. Risk assessments have been a component of most Population and Habitat Viability Assessments (PHVA) conducted by the IUCN CBSG; however, the value of these analyses has been limited by the lack of information and data on the prevalence of diseases in most species (Figure 2). It is critical to obtain objective data from health assessment programs that can be subjected to statistical tests to increase the accuracy of risk assessments (Munson and Karesh, 2002).

The development of standardized protocols for obtaining and assessing biological samples in every field project will make it possible to compare results obtained by different researchers in different places and periods of time. This will generate clinical and ecological knowledge on the role of pathogens and diseases in the population dynamics of jaguars in Mexico.

The jaguar epidemiological plan must start by determining baseline health parameters. The first step is to establish the normal values based on data already recorded, results of samples collected but not analyzed yet, and the analysis of samples opportunistically collected from healthy animals. As a general rule, the following baseline parameters should be established (Aguirre *et al.*, 1999; Brousset, 2005; Brousset *et al.*, 2006):

a) Clinical examination and morphometric data.
b) Hematological and biochemical parameters.
c) Serological tests for antibodies to infectious agents.
d) Virological parameters.
e) Bacteriological parameters.
f) Parasitological parameters.
g) Endocrinological parameters (to assess reproduction and population growth).
h) Toxicological parameters.
i) Pathological parameters.
j) Genetic parameters.

Diagnostic tests play a very important role in the health assessment of jaguars. These studies may involve laboratory tests to detect exposure to an agent (serology) or to detect and identify the agent involved in an animal's infection (bacteriological/virological tests) or mortality event (clinical pathology, gross pathology or histopathology). The tests may be used for epidemiological purposes to estimate the

Figure 1. Proper management of wild jaguars requires care and supervision by experienced veterinarians. Obtaining samples is essential to assess diseases in the wild. Photo: Gerardo Ceballos.

prevalence, incidence and geographical distribution of a specific infectious agent, or to determine the degree of infection in the population or the risk factor for a certain disease, including intra-or interspecific transmission.

The creation of a data bank on the health of Mexican jaguars will make it possible to carry out retrospective studies of samples already collected. These samples are a valuable source of information to understand the baseline health parameters of the species. The following steps can be taken:

a) Make an inventory of the material available, including tissue, blood serum and results of hematological and biochemical tests.

b) Develop a computerized data bank to record and fully identify historic samples, including data on the researcher, the individual the sample was taken from and the project through which it was obtained.

c) Establish the order of importance of the various tests the samples can be subjected to in order to obtain the maximum benefit from the data and identify critical information gaps.

Figure 2. Diseases are an important problem for jaguar conservation and other felids in the wild. The picture shows lesions caused by leishmaniasis on a jaguar's nose in the region of Caoba in Quintana Roo. Photo: Gerardo Ceballos.

d) The main objective of these tests will be the development of tools to assess the health of wild jaguars and contribute to the development of management strategies such as translocation and rehabilitation. Additional tests required will include standardization of serological tests to identify the presence of antibodies to specific viral and bacterial diseases in stored blood samples, histopathological assessment of stored tissue samples, identification of parasites, or molecular testing of museum specimens.

OFFICIAL ACTIONS AIMED AT JAGUAR CONSERVATION IN MEXICO: MID-TERM PERSPECTIVES

Oscar M. Ramírez Flores and Patricia Oropeza Hernández

Resumen

La Dirección de Especies Prioritarias para la Conservación, de la Comisión Nacional de Áreas Naturales Protegidas (Conanp) de la Semarnat, es la instancia gubernamental responsable de la recuperación de especies en riesgo de extinción, a través del Programa de Conservación de Especies en Riesgo, dentro de los cuales se incluye el jaguar, especie considerada en peligro de extinción en México. Con el apoyo de la Conanp se están realizando diversas actividades para la recuperación del jaguar, en las que participan distintas instancias de la administración pública, organizaciones no gubernamentales, instituciones académicas y habitantes de las regiones prioritarias para la recuperación de la especie.

Palabras clave: Áreas naturales protegidas, especies prioritarias, participación social.

Abstract

The Office for the Conservation of Priority Species from the National Commission of Protected Areas (Conanp) of the Ministry of the Environment (Semarnat), is responsible for the recovery of threatened species through the Threatened Species Conservation Program, which includes the jaguar, a species considered endangered in Mexico. With the support of Conanp, many actions for the recovery of the jaguar are taking place, where different agencies of the public administration participate, as well as non-governmental organizations, academic institutions and inhabitants of the priority areas for the recovery of the species.

Key words: Natural protected areas, priority species, social participation.

Introduction

The main problems for the conservation of the jaguar (*Panthera onca*) are caused by human activities, which have a huge direct and indirect impact on its populations. One of the most serious threats to the conservation of the species is habitat loss and fragmentation (Ceballos *et al.*, 2002; Medellín *et al.*, 2002). Because of its large size and broad distribution, the jaguar requires large areas to maintain viable populations. Therefore, protected areas are essential for the conservation of the species. However, few protected areas are large enough to maintain a viable jaguar population in the long term, and surrounding areas must be managed by creating corridors or implementing other measures. To conserve the jaguar, it is necessary to consolidate existing protected areas, to create new ones and to conserve the species in the large unprotected areas where it still occurs. These are key factors in jaguar conservation schemes (Hoogensteijn, 2000). In Mexico and the rest of Latin America, predation on domestic animals –especially cattle– is followed by lethal control measures taken by livestock farmers and breeders. Such measures take place even in protected areas and in the absence of predation events (Hoogesteijn and Mondolfi, 1992).

According to environmental regulations, the jaguar is considered a priority species for conservation in Mexico because of its ecological and social importance. The Mexican Wildlife Act (*Ley General de Vida Silvestre*) defines priority species as species considered to require special attention by the authorities because of their characteristics (i.e., keystone or flagship species whose recovery is feasible). The jaguar is also listed in the Mexican Endangered Species List (NOM.059 ECOL 2010). Hunting of jaguars was banned in the Diario Oficial de la Federación in 1987.

Over the last few years, great progress has been made in jaguar conservation in Mexico. This chapter is a summary of the actions taken by the Mexican government to conserve the jaguar in the long term, through the National Commission for Natural Protected Areas (Conanp) of the Ministry of the Environment (Semarnat).

Conservation of priority species

Until May 2005, the Unit for the Conservation of Priority Species (*Coordinación de Especies Prioritarias para la Conservación*) of the Wildlife General Directorate (*Dirección General de Vida Silvestre*) was in charge of the conservation of priority species. This responsibility has since been transferred to Conanp, according to the regulations of Semarnat, published in November 2006.

Conanp's conservation scheme is based on three pillars: Species, Space and Social Welfare, given that the conservation of priority species is only considered to be possible by promoting social welfare. For the period 2007-2012, Conanp has planned five structural programs aimed at conserving priority species and reducing the rate of biodiversity loss by 2010.

The programs are the following: 1) Increase of protected areas and consolidation of regional conservation systems. 2) Development of the Tourism Program in protected areas. 3) Implementation of conservation for development strategies. 4) Development of the Conservation Program for Endangered Species (Procer). 5) Promotion of conservationism.

In this strategy, Procer has established the need to set priorities between the threats affecting priority species by means of Action Plans for Species Conservation (PACE). These action plans are planning documents that establish the priorities, instruments and actions chosen to reach the conservation goals for each priority species. Every plan has a formal structure with technical, financial, infrastructure and human resources, and includes components involving protection, management, knowledge, culture, assessment and monitoring.

Jaguar as a priority species

Recent conservation actions started with the formal creation of a group of specialists and other people interested in the jaguar's conservation and the study of its biology and ecology. The Mexican Technical Advisory Subcommittee for Jaguar Conservation and Management was established in 2000. In 2006, the Subcommittee published the Project for the Conservation and Management of Jaguar in Mexico in the series Recovery Projects for Priority Species (PREP). The Project contains the general guidelines for the conservation of the species and its habitat (Figure 1; Ceballos *et al.*, 2006). The need to develop the Acction Plan for the Conservation Species: Jaguar (PACE: Jaguar), this document established actions a short, medium and large term, using the recomendations of PREP. The technical and management elements that should be included in the Action Plan were identified in a consultation process between the academic sector, civil society, the media and various government sectors involved in projects related to the jaguar in Mexico. The program has developed several pillars described below as the basis for its conservation actions.

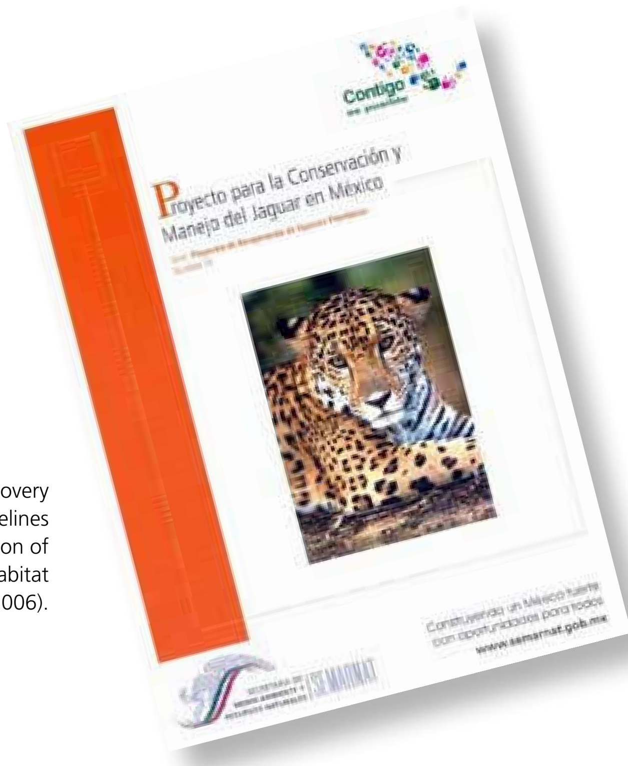


Figure 1. Jaguar Recovery Project includes the guidelines for the conservation of the species and its habitat (Ceballos *et al.*, 2006).

Planning and analysis

Local initiatives have been promoted to develop state-level strategies for jaguar conservation in Jalisco, Oaxaca, Nayarit, Michoacán, Chiapas and San Luis Potosí. Close monitoring is necessary to consolidate these actions.

Several academic meetings and events have focused on jaguar conservation actions, such as the meeting on "Ecological importance of the jaguar in biodiversity conservation in the state of Oaxaca" and the "Day of the Jaguar" in Sinaloa. The first and second editions of the Symposium "The Mexican Jaguar in the 21st Century" were coordinated by the Wildlife Ecology and Conservation Laboratory of the Institute of Ecology, UNAM. The symposia were sponsored by institutions such as Alianza WWF México - Telcel, UNAM, Conanp and Conabio and held in October and November 2005 and 2006, respectively. These meetings bring together specialists in jaguar research and conservation in Mexico. The findings of the first symposium were published in 2006 (Figures 2 and 3; Chávez and Ceballos, 2006). The third symposium will be held in November 2007 .

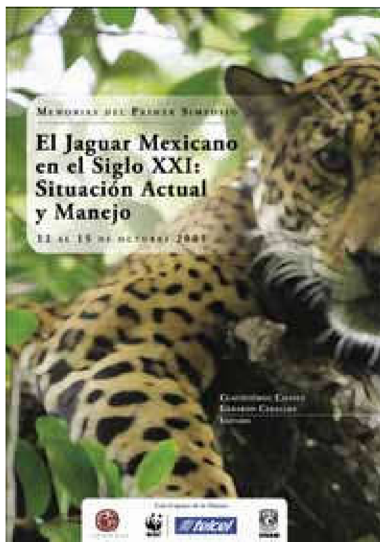


Figure 2. The First Symposium "The Mexican Jaguar in the 21st Century" (Chávez and Ceballos, 2006) compiles the proposals made by experts for the conservation of the species.

Figure 3. The symposia "The Mexican Jaguar in the 21st Century" bring together specialists in jaguar research and conservation in Mexico.
Photo: Gerardo Ceballos

The Technical Advisory Subcommittee for Jaguar Conservation and Management met in May 2007 with other stakeholders from the academic and social sectors to explain the strategy followed by Conanp to deal with endangered species. The participants discussed legal instruments such as Jaguar Action Plan, which establishes the working plan and the management of conservation projects for endangered species and fulfills the 5 presidential commitments to conservation declared by the Mexican President on 24 February 2007.

Four main actions for 2007 were defined at the meeting: 1) Increase connectivity between protected areas and biological corridors in the Maya Forest; 2) conduct the First National Jaguar Survey; 3) draw up a program to deal with events of predation on livestock by large felids (jaguars and pumas); and 4) set up an awareness-raising and environmental education program for jaguar conservation and its habitat.

Awareness-raising

A key action taken by Conanp to raise national awareness about the conservation plight of jaguar was to designate 2005 as the Year of the Jaguar. The strategy was supported by Mexican President. The Year of the Jaguar led to other awareness-raising initiatives such as "20 Jaguar," a traveling exhibit organized by a group of graphic and plastic artists through *Asociación Civil Pueblo Jaguar Oaxaca* where more than 40 artists participated (Figure 4). The artists donated works inspired by jaguar to raise funds to support productive projects such as compensation payments for livestock predation caused by jaguars in several communities of the region of Chinantla. Other actions taken by various players and bodies included posters, brochures and leaflets on jaguar conservation, which have been circulated in governmental and non-governmental institutions.

Conservation

The conservation strategy for jaguar habitat implies consolidating protected areas where jaguar populations are present, creating new protected areas, and promoting habitat conservation in buffer zones or areas adjacent to reserves through incentives such as payments for ecosystem services. For example, 38,000 hectares have now been declared a protected area in Sierra de Vallejo, Nayarit, 150,000 hectares have been added to Calakmul Biosphere Reserve in Campeche, and Bala'an Ka'ax Flora and Fauna Protection Area was established in Quintana Roo. A private reserve of Naturalia, A.C. was also established in Sonora, the northernmost region of the species' range in Mexico.

To promote habitat conservation, Conanp has signed an agreement with the National Forestry Commission (Conafor) to encourage projects providing payments for ecosystem services –hydrological services and carbon capture– and biodiversity conservation, giving priority to areas considered important for the conservation of the species.

Surveillance and protection

In 2005, Conanp signed an agreement with Conabio, the Mexican National Commission for the Knowledge and Use of Biodiversity, to develop a project in cooperation with Profepa, the law enforcement arm for environmental protection, Asociación Civil Hombre Jaguar Nayarit and agricultural and municipal authorities to set up and equip 50 Community Watch Committees in 12 states where the jaguar occurs (Oropeza *et al.*, this volume). In almost three years of efforts to promote and monitor community watch schemes, Profepa teams have worked in the states of Campeche, Chiapas, Jalisco, Michoacán, Nayarit, Oaxaca, Querétaro, Quintana Roo, Sinaloa, Tabasco, Veracruz and Yucatán. Staff of 8 protected areas have also been involved, namely those of the Biosphere Reserves Sierra de Manantlán, Sierra Gorda, La Encrucijada, Los Petenes, Ría Lagartos, Calakmul and Ría Celestún, and Naha and Metzabok Flora and Fauna Protection Areas. Non-governmental organizations and municipal and other local authorities of more than 50 municipalities and 70 communities in 14 jaguar range states have also participated.

The "First Community Watch Workshop for the Conservation of the Jaguar and its Habitat" took place in 2007. It brought together over 50 participants, including community watch staff in 13 states, researchers and representatives of government bodies involved in this effort (Conanp, Profepa, and Conabio). The workshop was fi-

Figure 4. One of the awareness-raising initiatives was the travelling exhibition entitled "20 Jaguar," where more than 20 artists participated. The author of this painting is Gabriel Coto, a Cuban artist.
Photo: Gerardo Ceballos

nanced by Conanp and had an excellent response by speakers and other participants. One of its products was the Telchac Declaration, which includes the commitments taken on by Conanp, Profepa and the community watch committees.

Profepa has also created an official database on the number of seizures and confiscations of jaguar specimens, parts and derivatives over the last few years, with the aim of making an official diagnosis on the severity of poaching in jaguar populations in Mexico. Several interinstitutional efforts have been made to deal with conflicts between jaguars and livestock farmers. The first official attempts to approach the issue took place in 2005 and 2006. They involved meetings of Conanp with the Livestock Farming Unit of the Ministry of Agriculture, Fisheries and Food (Sagarpa), the private sector and the academic sector of the National Autonomous University of Mexico (UNAM) to try to reach an agreement between both ministries to deal with the problem.

International agreements

In the framework of international jaguar conservation schemes, Mexico signed the initiative *Jaguares sin Fronteras* (Jaguars without Borders) with Belize and Guatemala in 2006. The aim of the strategy is to twin protected areas of these three countries to promote joint conservation efforts. Some of the management actions selected are control of forest fires and illegal wildlife trade, management of protected areas and environmental impact assessment of public infrastructures to try to reduce the threats of this critical region. The first steps of the initiative began in 2004 with contact meetings to make a SWOT analysis of a possible joint working strategy with Guatemala and Belize in a highly vulnerable area from an ecological, social and political point of view. Two more meetings took place in 2005 and 2007 to assess the progress made and plan tasks to reach the conservation objectives of this important biological corridor. The three countries take turns at chairing this initiative, and it is currently being chaired by Belize.

At the same time, a workshop entitled Paseo Jaguar (Spanish for "path of the jaguar") was organized to discuss a proposal made by the Wildlife Conservation Society (WCS) to conserve the jaguar and its habitat. The proposal implies linking jaguar habitat from southeastern Mexico to Argentina by means of biological corridors. Representatives of academia, government and civil society of each of the seven countries in Central America, with the exception of El Salvador, were invited to the meeting to develop a working program based on research and conservation input from each country and analyze possible sites and funding programs by WCS. Mexico, Guatemala and Belize made a joint opening statement explaining the strategy of Jaguars without Borders and inviting WCS and participating countries to attend the next meeting to learn about the work that is under way.

Final considerations

Conanp is currently funding eight projects and events aimed at conserving the jaguar and its habitat, implementing actions that were given priority in the meeting with the specialists of the Technical Advisory Subcommittee. The projects and events began in May and will conclude at the end of the 2006-2007 fiscal year. They include the National Jaguar Survey, five regional pilot projects dealing with livestock predation by jaguars in the Sierra Oriental, Western Corridor, Southern Pacific, Yucatan Peninsula and Maya Forest, a National Strategy and Diagnosis to tackle the Jaguar-Livestock conflict, a national awareness-raising and communication strategy to conserve the jaguar and its habitat, a strategy to interconnect protected areas in the Maya Forest, and three regional community watch workshops for the conservation of the jaguar and its habitat, some of which are already under way.

These actions are aimed at obtaining the necessary basic input to develop more specific strategies in the different regions. The objectives are to conserve habitat connectivity and viability, reduce the loss of jaguar individuals and populations, and consolidate a jaguar research and conservation specialist group.

DISEASES OF WILD JAGUARS IN SOUTHEASTERN MEXICO

Marcela A. Araiza, Gerardo Ceballos,
and Cuauhtémoc Chávez

Resumen

Los grandes felinos silvestres sirven como un indicador de cambios en los ecosistemas. Estudios recientes demuestran que las enfermedades infecciosas tienen efectos devastadores en sus poblaciones. La conversión del hábitat debido a actividades antropogénicas ha aumentado la incidencia de enfermedades en la fauna silvestre, por lo que es importante identificar las enfermedades que los afectan, así como las condiciones ecológicas asociadas con su severidad y dispersión. En este estudio se evaluó y contrastó la seroprevalencia de enfermedades virales y bacterianas, la presencia de parásitos, y algunos parámetros hematológicos del jaguar en la Reserva de la Biosfera Calakmul, Campeche, y el Ejido Caoba, Quintana Roo. Los dos sitios tienen influenza de actividades antropogénicas, que es más intensa en el ejido. La seroprevalencia de enfermedades transmitidas por animales domésticos (parvovirus canino/panleucopenia felina) en el fue de 8%, la de por vectores (gusano felino del corazón) 86.6% y la de reservorios silvestres (toxoplasmosis) de 55.5% en el Ejido Caoba. En contraste no se encontraron anticuerpos para estas enfermedades en la Reserva de Calakmul. Se encontraron anticuerpos contra *Burcella abortus* en el único macho de la Reserva analizado y en uno de 8 animales muestreados en el Ejido Caoba. No se encontraron anticuerpos contra el virus de inmunodeficiencia felina, coronavirus felino, *Chlamydia*, ni evidencias del antígeno de leucemia viral felina para ningún sitio. Los cambios de hábitat debido a las actividades humanas podrían ser la causa de las seroprevalencias mayores en el Ejido Caoba. Los parámetros hematológicos de los ejemplares capturados en la Reserva son más parecidos a los valores obtenidos en animales en cautiverio; en el Ejido Caoba, los valores difieren de los animales en cautiverio principalmente en la fórmula leucocitaria.

Palabras clave: *Brucella*, enfermedades en fauna silvestre, leucemia viral, moquillo, parvovirus, toxoplasmosis.

Abstract

Large felids are indicators of ecosystem changes. Recent studies show that infectious diseases have devastating effects in their populations. Furthermore, habitat conversion due to anthropogenic activities has increased incidence of wildlife diseases, therefore, besides ecological data, it is important to identify both, the diseases potentially important to large *carnivores, and the ecological conditions associated with their expansion and severity. The seroprevalence of viral, bacterial and parasitic diseases and some hematological parameters were evaluated in wild jaguars from two places of Southern Mexico; the Calakmul Biosphere Reserve and Ejido Caoba. In Ejido Caoba, the seroprevalence of diseases transmitted by domestic carnivores (canine parvovirus/feline panleukopenia) was 8 %, by vectors (feline heart worm) 86.6 %, and by wild reservoirs (Toxoplasma) 55.5 %, while no antibodies were found within the Reserve. Antibodies against* Brucella abortus *was found in the only male tested in the Reserve, and from one of 8 jaguars in Ejido Caoba (12.5%). Antibodies against feline immunodeficiency virus, feline coronavirus,* Chlamydia *and feline leukemia were not found. Habitat changes due to the human activities could be responsible for the greater seroprevaence in Ejido Caoba. The hematological parameters of wild jaguars from the Reserve are more similar that the values of captive jaguars, in Ejido Caoba, these values are different from the values of captive jaguars, mainly in the leukocyte formula.*

Key words: Brucella, *viral leukemia viral, distemper, parvovirus, toxoplasmosis, wildlife diseases.*

Introduction

Carnivores are very sensitive to habitat disturbances; their decline and disappearance are indicators of changes in ecosystems (Coté and Sutherland, 1997; Crooks and Soulé, 1999; Estes, 1996; Gittleman *et al.*, 2000). Strict carnivores of a large size that live in isolated populations and disperse great distances are more likely to become extinct (Purvis *et al.*, 2001; Woodroffe, 2001). Recent declines in wild carnivore populations have shown that infectious diseases have devastating effects on their conservation (Murray *et al.*, 1999). Habitat conversion due to anthropogenic activities has enhanced the role of diseases as regulators of survival in carnivores (Deem *et al.*, 2001; Dobson and Foufopoulos, 2001; Funk *et al.*, 2001). As populations of domestic ungulates and carnivores increase, generalist pathogens are more likely to spread to less abundant populations of wild carnivores (Funk *et al.*, 2001; Holmes, 1996). Habitat reduction also causes a concentration of species and individuals in remnant areas. This increases the rate of transmission of infectious agents, negatively affects nutritional status and increases stress, which makes species more susceptible to diseases and other population pressures (Deem *et al.*, 2001; Patz *et al.*, 2000; Scott, 1988). The effect of pathogens can shift from compensatory to additive. Even if mortality is compensatory, the population may be affected if pathogens decrease the reproductive rate or change the age structure (Funk *et al.*, 2001). At the edge of protected areas and in corridors, diseases can be the key factor preventing a population from persisting and dispersing successfully to other areas (Simberlof and Cox, 1987; Simoneti, 1995).

To prevent declines in carnivore populations, it is important to identify the diseases that affect them as well as the ecological conditions associated to their severity and spread (Murray *et al.*, 1999). Therefore, ecological data are not enough for a carnivore conservation project to be successful. Diseases and infectious agents of the target species and possible reservoirs of diseases must also be taken into account (Funk *et al.*, 2001). In the wild, large felids are susceptible to diseases that are common in domestic dogs and cats, such as canine distemper, canine parvovirus, feline panleukopenia (Roelke *et al.*, 1993), and feline leukemia (Appel *et al.*, 1994; Blythe *et al.*, 1983; Fix *et al.*, 1989; Jessup *et al.*, 1993; Kock *et al.*, 1998; Parish, 1999; Paul-Murphy *et al.*, 1994; Roelke-Parker *et al.*, 1996; Richard and Foreyt, 1992). Antibodies against feline immunodeficiency virus have been found, although there was no evidence of associated disease (Barret, 1999; Brown *et al.*, 1994; Jarret, 1999; Spencer *et al.*, 1992).

The jaguar, one of the most endangered carnivores in Mexico, is used as an indicator to determine priority areas for conservation and make decisions about the appropriate size of protected areas and where to establish corridors between them (Ceballos *et al.*, 2005). Besides information about home ranges and activity patterns, the health of these populations must be taken into account. In spite of the importance of diseases and the health status of populations for conservation, there is no information about the seroprevalence of infectious diseases in wild populations of jaguars in Mexico or normal blood values of wild populations. Therefore, the aim of this study was to assess the seroprevalence of diseases and determine blood values of wild jaguars in a protected area –Calakmul Biosphere Reserve– and a fragmented environment –Ejido Caoba.

Methods

Jaguars were captured in Calakmul Biosphere Reserve, in Campeche, and Ejido Caoba, in Quintana Roo, from 2002 to 2005 (see Ceballos *et al.*, 2002; Chávez, 2006). The animals were immobilized with a mixture of xylazine (0.7-1.3 mg/kg) and ketamine (7.6-11 mg/kg). On some occasions anesthesia was reversed with yohimbine (0.125 mg/kg). A complete physical examination was performed, and antibiotics and anthelmintics were administered when necessary. Ectoparasites were collected, and 10 ml of blood was collected from the tarsal or femoral vein. After placing 1 ml of blood in tubes with EDTA anticoagulant, the samples were sent to the laboratory to obtain the blood values. The remaining blood was centrifuged to obtain serum and stored at -20°C until it was tested.

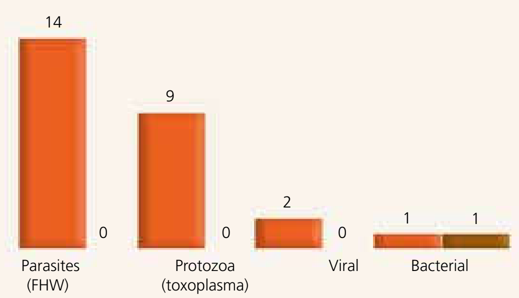
Seroprevalence of diseases was determined with the following commercial tests, and following the manufacturer's instructions: feline heartworm (FHW Antibody Test, Witness ®), feline immunodeficiency virus and feline leukemia virus (Snap FIV/FeLV, IDEXX), canine distemper (CDV IMMUNOCOMB® IgG antibody test kit), canine parvovirus (CPV IMMUNOCOMB® IgG antibody test kit), feline coronavirus (FCoV-FIP IMMUNOCOMB® antibody test kit), Toxoplasma and Chlamydia (Feline Toxo

& Chlamydia IMMUNOCOMB® Ab test kit). Seroprevalence of Brucella was determined at the Center for Research and Advanced Studies in Animal Health (CIESA) of the Autonomous University of the State of Mexico (UAEM) with the card test. Student's t-test was used to assess the differences in blood values between the two sites and the differences in the mean number of ectoparasite larvae.

Results and discussion

Samples were taken from 23 jaguars –19 in Ejido Caoba (9 females and 10 males) and 4 in Calakmul Biosphere Reserve (3 males and 1 female)–. Five jaguars were recaptured. All the jaguars were in good physical condition; most of them had scars or parts of their ears missing from fights. Three jaguars had lost tissue in their face, with similar lesions to those caused by cutaneous leishmaniasis.

There were differences in the presence and seroprevalence of diseases transmitted by domestic animals between Calakmul Biosphere Reserve and Ejido Caoba (Figure 1, Table 1). Between 1 and 50 (X = 13.8) larvae of the fly *Dermatobia hominis* were taken from 15 jaguars (Figure 2). The mean number of *Dermatobia* larvae was higher in Ejido Caoba than in Calakmul (18.2 and 3.7 respectively; P= 0.0296). In Ejido Caoba, seroprevalence of canine parvovirus/feline panleukopenia was 8%, that



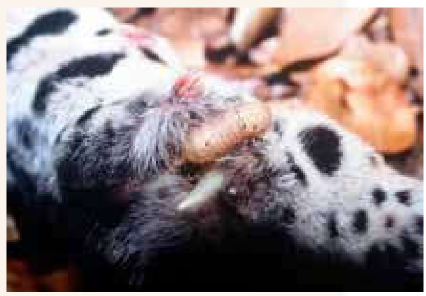


Table 1. Seroprevalence of diseases in wild jaguars captured in Calakmul Biosphere Reserve and Ejido Caoba in Quintana Roo, Mexico

Diseases	Caoba	N	Calakmul	N
FeLv	0 %	16	0 %	3
FIV	0 %	16	0 %	3
FCoV	0 %	16	0 %	3
Chlamydia	0 %	16	0 %	3
Canine distemper	0 %	18	0 %	3
Canine parvovirus	8 %	18	0 %	3
Toxoplasma	55.5 %	16	0 %	3
FHW	86.6 %	16	0 %	3
Brucella abortus	12.5 %	8	100%	1

Figure 1 Number of jaguars with antibodies against viral, bacterial and parasitic diseases in Calakmul Biosphere Reserve and Ejido Caoba in Quintana Roo, Mexico.

Figure 2 (above). Larvae of the bot fly *Dermatobia hominis*.

of vectors (i.e., feline heartworm) was 86.6% and that of toxoplasmosis was 55.5%. However, no antibodies to these diseases were found in the biosphere reserve (Table 1). Antibodies against *Brucella abortus* were found in the only male in the Reserve that was tested for the disease, and in one of 8 animals tested in Ejido Caoba. No antibodies against feline immunodeficiency virus, feline coronavirus or *Chlamydia* were found in either site, nor was any evidence of the feline leukemia virus antigen (Table 1). The mean blood values of wild jaguars captured in Calakmul Biosphere Reserve are more similar to mean values obtained in captive animals (Deem, 2002) than values of jaguars captured in Ejido Caoba (Table 2; Figures 3 - 4).

Table 2. Comparison of blood values (t-student) of wild jaguars of Calakmul Biosphere Reserve and Ejido Caoba in Quintana Roo, Mexico, with blood values of captive jaguars (Deem, 2002)

Blood Values	Caoba-Calakmul	Reference Caoba	Reference Calakmul
Hematocrit	0.312	0.0004	0.3768
Hemoglobin	0.165	0.5182	0.1421
MCHC	0.829	0	0.0023
MCV	-	0	-
MCH	-	0.2815	-
Platelet count	-	0.2017	-
RBC	-	0.3192	-
WBC	0.314	0.0002	0.2759
Neutrophils	0.264	0.0501	0.838
Lymphocytes	0.985	0.0044	0.1171
Eosinophils	-	0.0005	

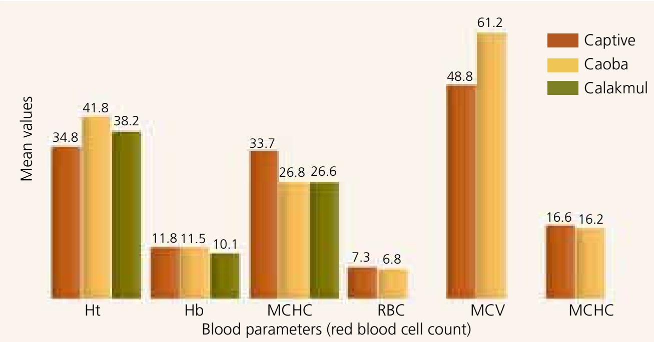


Figure 3. Mean values of blood parameters (red blood cell count) of captive and wild jaguars in southeastern Mexico. Data for captive jaguars were taken from Deem (2002).

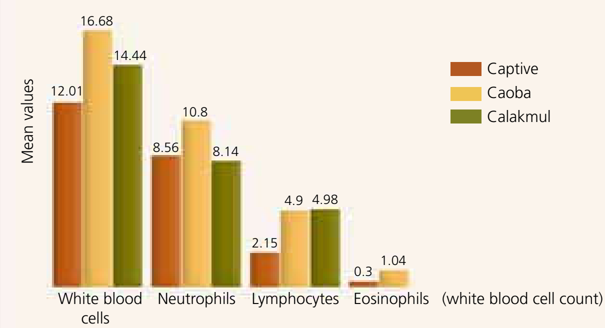


Figure 4. Mean values of blood parameters (white blood cell count) of captive and wild jaguars in southeastern Mexico. Data for captive jaguars were taken from Deem (2002).

Bloody feces were observed in one of the two males with antibodies against parvovirus/panleukopenia; this is the main characteristic of acute infection (Steinel *et al*, 2000). Although it is not known whether parvovirus/panleukopenia affects populations of wild felids, a high prevalence has been associated to a greater mortality in the offspring of other wild carnivores (Creel *et al.*, 1997; Johnson *et al.*, 1994; Mech and Goyal, 1995). The prevalence of these viruses in wild carnivores has been related to the presence and proximity of domestic cats and dogs, a large home range and long dispersal distances (Biek *et al.*, 2002; Hofman-Lehmann *et al.*, 1996; Riley *et al.*, 2004). There is no information about the prevalence of these viruses in domestic carnivores of the region. Yet, if domestic dogs in Ejido Caoba were affected by an epizootic, it could have a negative impact on the jaguars, mainly through offspring mortality. In this area, it is common for dogs to be present in the home range of jaguars, alone or with hunters; dogs are occasionally predated by jaguars (M. Araiza, pers. obs.), which increases the risk of contagion. These viruses are shed in feces and are very resistant to high temperatures and droughts, so they remain infective for months (Gordon and Angrick, 1986; Steinel *et al.*, 2001).

No antibodies against canine distemper were found, which shows either that jaguars die after being exposed to the virus or that they have never had contact with it (Table 1); the second scenario is dangerous because a distemper epizootic could cause a high mortality, as has happened in other populations of wild felids (Apel, 1987; Roelke-Parker *et al.*, 1996). This scenario is more likely in areas with greater fragmentation and contact with dogs. Jaguars whose home range is on the boundary of Calakmul Biosphere Reserve and that have greater contact with human settlements have a greater risk of acquiring the virus. In the case of parvovirus/panleukopenia and distemper, direct contact between jaguars and dogs is not necessary, because prey species such as procyonids and mustelids are susceptible to the disease and can acquire it from dogs and transmit it to jaguars (Green, 1993; Parrish, 1999).

Like all vector-borne diseases, seroprevalence of antibodies against *Dirofilaria* (heartworm) depends of environmental factors that affect its reproduction, growth, survival, transport and the spread of the infectious agent. In other areas, the transmission of heartworm is seasonal (Watts *et al.*, 2001). The minimum temperature at which vector mosquitoes survive is 14° C, and conditions are more favorable when mean temperatures are above 20° C (Vezzani *et al.*, 2006). In the biosphere reserve and Ejido Caoba, mean annual temperature is favorable to the survival of *Dirofilaria* vectors (26° C). However, the presence of *Dirofilaria* is affected by the availability of breeding sites for its vectors. A high prevalence of heartworm and other diseases transmitted by vector mosquitoes has been associated to riparian areas, to the accumulation of water in areas with high rainfall, and droughts in tropical areas where people store water in open containers (Gortazar, 1994; Linthicum *et al.*, 1988; Moore *et al.*, 1978; Sheppard *et al.*, 1969). Deforestation exposes water containers to more sunlight, which improves the conditions of breeding sites for vectors (Walsh *et al.*, 1993). In Ejido Caoba, human activities such as the changes in land use and a greater availability of stored water may be contributing to an increase in the vectors that transmit *Dirofilaria*. The high seroprevalence found in Ejido Caoba could become a public health problem, since *Dirofilaria* can be transmitted to humans and cause pulmonary nodules (Miyoshi *et al.*, 2006; Narine *et al.*, 1999; Rodrigues-Silva *et al.*, 1995).

The difference in the seroprevalence of toxoplasma between Ejido Caoba and the Biosphere Reserve may also be due to changes in land use caused by human activities; this has been associated to a high prevalence of toxoplasma in other wild animal species (Anwar *et al.*, 2006; Gaydos *et al.*, 2007; Kikuchi *et al.*, 2004; Roser-Degiorgis *et al.*, 2006) and humans (Etheredge *et al.*, 2004; Frenkel and Ruiz, 1981). Human constructions and activities compact the soil, creating favorable conditions for the survival of toxoplasma oocysts. Prevalence is also high in areas with a greater proportion of water bodies, which create a favorable microclimate for oocysts (Zarnke *et al.*, 2001). It is very important to take preventive measures against the transmission of toxoplasma. In humans, it causes reproductive problems such as miscarriages, reduces psychomotor development (Flegr, 2007) and is associated to a greater number of cases of schizophrenia (Torrey *et al.*, 2006). Water contaminated with feces of wild felids has been a source of transmission of toxoplasmosis epidemics in humans; domestic dogs act as mechanical vectors, by rolling in feces of wild or domestic felids (Aramini *et al.*, 1999; de Moura *et al.*, 2006; Frenkel *et al.*, 1995; Lindsay *et al.*, 1997).

As regards the antibodies against *Brucella abortus* found in one jaguar of the reserve and one in Ejido Caoba, there are no records of its prevalence in wild animals in these areas. Yet, the disease may be present in cattle and goats in the region. The higher white blood cell values of jaguars in Ejido Caoba suggests that they may be suffering from chronic or acute inflammatory processes, inflammatory conditions due to antigenic stimulation, or parasitic infestations (Rebar *et al.*, 2005). Although an increase in these values can be caused by stress or the handling of the animals, the method used to capture the jaguars and handle the samples was the same in the biosphere reserve and Ejido Caoba. Therefore, the results may reflect the health status of the population.

Finally, this study highlights the importance of assessing the health status and the prevalence of diseases in wildlife. It is therefore necessary to continue to study the jaguar population in the region but also broaden the study to other species to understand the mechanisms of transmission and the role of domestic animals in the process.

POPULATION AND HABITAT VIABILITY ASSESSMENT OF JAGUARS IN MEXICO

Luis Carrillo, Gerardo Ceballos, Cuauhtémoc Chávez, Juan Cornejo, Juan Carlos Faller, Rurik List, and Heliot Zarza
Editors

Resumen

El presente trabajo es el resultado del *2° Simposio El Jaguar Mexicano en el Siglo XXI*: Taller de Análisis de la Viabilidad de Poblaciones y del Hábitat llevado a cabo en el Club de Golf de Cuernavaca, Morelos, México, del 21 al 24 de noviembre, 2006. México es un reducto importante para del jaguar (*Panthera onca*), pero la continua pérdida del hábitat y cacería furtiva, ha hecho necesario evaluar la viabilidad de la especie para determinar las estrategias para su conservación. Utilizamos el programa VORTEX para identificar los factores que tienen un mayor efecto en la probabilidad de extinción. Estos son: número de crías por camada, incremento en el número de hembras reproductivas, reducción de la edad reproductiva máxima de las hembras, y mortalidad de hembras y crías. La mortalidad resultante de la cacería furtiva reduce significativamente el crecimiento poblacional e incrementa el riesgo de extinción de las poblaciones más pequeñas. El efecto es más pronunciado en hembras, ya que cuando se elimina a más del 3% de la población de hembras, la población no es viable en un período de 100 años. Los tamaños poblacionales inferiores a 100 individuos no son viables. Las poblaciones de las 5 regiones prioritarias para la especies fueron evaluadas, considerando la pérdida de hábitat, la capacidad de carga, y la cacería furtiva, donde las poblaciones de Sonora y Tamaulipas al norte, están en un mayor riesgo, y la población de la selva maya en el sur, es viable a largo plazo. Se identificaron vacios de información, participantes clave y acciones que pueden reducir los factores de riesgo e incrementar la viabilidad de la especie a largo plazo en México.

Palabras clave: cacería furtiva, riesgo de extinción, viabilidad poblacional.

Abstract

*This work is the result of the 2nd Symposium: The Mexican jaguar in the XXI Century: Populations and Habitat Viability Analisis, which took place in Cuernavaca's Golf Club, in Morelos, Mexico, from November 21 to 14, 2006. Mexico is an important stronghold for the jaguar (*Panthera onca*), but with ongoing habitat loss and jaguar poaching throughout the country, it became necessary to assess the viability of the species to determine the strategies for their conservation. We used program VORTEX to identify the factors that have a greater effect on the probability of extinction. These are; number of cubs per litter,* *increase of reproductive females and reduction of female's maximum reproductive age, female and cub mortality. Poaching mortality significantly reduces population growth and increases the risk of extinction of the small populations. This effect is stronger in females, as when take is over 3% of the female population, extinction makes populations non-viable over 100 years. Population sizes < 100 individuals are not viable. The populations of the five different jaguar regions were assessed, taking into account habitat loss, carrying capacity and poaching, with the Sonora and Tamaulipas populations, in the temperate north, being at greater risk, and the Selva Maya in the tropical south being viable in the long-term. Information gaps were identified, as well as key players and actions which can reduce the risk factors and increase long-term viability of the jaguar in Mexico.*

Key words: extinction risk, poaching, population viability.

Introduction

The jaguar is the largest predator in the Neotropics. The accelerated destruction of its habitat and poaching have been identified as the main causes of the decline in jaguar populations (Ceballos *et al.*, 2006; Medellín *et al.*, 2002; Nowell and Jackson, 1996). Few studies have assessed the status of the populaitons across its range (Sanderson *et al.*, 2002). Over the last 20 years, efforts have been made to assess the species' distribution by means of interviews, fieldwork, and expert workshops (Ceballos *et al.*, 2006; Medellín *et al.*, 2002; Sanderson *et al.*, 2002; Swank and Teer, 1989). The assessments have concluded that the species has been extirpated from a considerable part of its historical range.

The jaguar is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 1998). It is listed as endangered in the Mexican Endangered Species List (Semarnat, 2002), and an indefinite on jaguar capture or killing has been in place since 1987 (Sedue, 1987). In spite of this, jaguar conservation efforts have been limited. There is a lack of regional strategies, and a solid and reliable national strategy for jaguar conservation is also needed in Mexico.

The interest of many groups and individuals in jaguar conservation in Mexico led to the creation of the Mexican Technical Advisory Subcommittee for Jaguar Conservation and Management in 2000, as part of the Priority Species Recovery Program of the Ministry of the Environment and Natural Resources (Semarnat). Researchers of academic institutions, representatives of governmental and non-governmental organizations, and individuals interested in policies and strategies related to jaguar conservation are actively involved in the Subcommittee. The "Project for the Conservation and Management of the Jaguar in Mexico" was published in 2006. It defines the main threats to the jaguar, identifies areas where there are still populations of the species in Mexico, and defines actions aimed at jaguar conservation (Ceballos *et al.*, 2006).

The First Symposium "The Mexican Jaguar in the 21st Century: Current Status and Management" was held in 2005. At the symposium, a group of specialists assessed the status of jaguar in Mexico, including biological and management aspects, habitat conservation, and the relation between jaguars and humans (Chávez and Ceballos, 2006). The experts concluded that a Population and Habitat Viability Assessment (PHVA) of the species in Mexico was needed. The various priority regions for jaguar conservation that should be included were: 1) Maya Forest, 2) Ría Lagartos, 3) Jalisco-Nayarit, 4) Sonora, 5) Zoque Forest, and 6) Tamaulipas, as there is enough quality data on the species to generate reliable models.

Consequently, the 2nd Symposium "The Mexican Jaguar in the 21st Century: Workshop on Population and Habitat Viability Assessment" was organized in 2006 by the Institute of Ecology of the National Autonomous University of Mexico (UNAM) and the National Commission for Natural Protected Areas (Conanp), with the support of Alianza WWF-Telcel and the Arizona Game and Fish Department. The workshop was facilitated by experts of the IUCN/SSC Conservation Breeding Specialist Group. The objective was to focus on reducing the probability of extinction of the jaguar in Mexico by identifying, prioritizing and implementing management actions and conservation policies, and serve as a guide towards a management plan for the species.

Objectives of the workshop

General objective

Propose an Action Plan establishing the strategies for jaguar conservation in Mexico.

Specific objectives

1. Bring together researchers and decision makers involved in the study, management, protection and conservation of the jaguar in Mexico.
2. Compile all the current technical, scientific and empirical information available on the ecology, population dynamics, genetics, conservation status, environmental factors, threats, and management and conservation measures regarding the species in Mexico.
3. Make a diagnosis of the current status of jaguar populations and an objective assessment of the extinction risk of the species according to the information available.
4. Define needs and priorities for the protection and conservation of the species.
5. Discuss and propose general recommendations for the research, management and conservation of the species.
6. Prioritize the necessary measures, mentioning timeframes, needs, institutions or people in charge and participating institutions with financial or legal support.

Methods

In PHVA workshops, participants first agree on the objectives of the meeting –preventing the extinction of the species and maintaining viable populations. The PHVA process involves a thorough review of the species' ecology, populations, conservation status, threats and conservation measures. One of the most important results of PHVA workshops is the amount of unpublished information that they collect. It is estimated that 80% of useful information on a given species is in the minds of experts and may never be published. This information provides the basis to build simulations for each population by using a model that makes it possible to analyze deterministic and stochastic effects, as well as the influence of genetic, demographic and environmental factors and catastrophes on population dynamics and extinction risk. Information is included in the model in the form of assumptions and data available to explain the assumptions. This process leads to building a basic model of the species by consensus. The model simulates the species' life history, according to current knowledge, and makes it possible to continue discussing adaptive management options for the species or the population as more information becomes available. Finally, it is possible to set up management plans that are continuously reviewed in the light of new information, as a scientific exercise, and can be adjusted as necessary.

In a PHVA, all participants are equal and all contributions must be acknowledged for the process to be successful. Information provided by researchers, peasants, park rangers, hunters, local residents, etc. is of equal importance. Communication is an important value in a PHVA process. It often involves different people who have worked on the same species for years but have never shared information face to face. In a PHVA workshop, participants work in small groups to discuss issues that have previously been selected as crucial for the species' recovery, such as prevention of mortality, habitat conservation, management of prey species, human pressures, captive breeding, and so on.

Worshop on jaguar (*Panthera onca*) conservation in Mexico –Population and Habitat Viability Assessment– Working Methodology

The Workshop on Population and Habitat Viability Assessment took place from 21 to 24 November at the Cuernavaca Golf Club in Morelos, Mexico.

Based on the challenges for the conservation of the species, three working groups were established by the group and the facilitators: "Habitat conservation and management", "Interrelation between the jaguar and society" and "Population biology and extinction risk." Each working group was charged with the following tasks:

- Discuss the problems of the species.
- Prioritize such problems.
- Develop a list of short term and long-term targets for each of the problems.
- Develop and prioritize detailed actions for each of the high-priority issues.

• Identify the different kinds of resources needed to implement the actions.

Each group presented the results of its discussions in plenary sessions to ensure that all participants had the chance to contribute to the work of other groups and that each topic was reviewed and discussed by the whole group.

To estimate the risk in possible future ecological scenarios, the group dealing with "Population biology and extinction risk" used a simulation model –VORTEX– and identified critical factors for population decline. It also considered a number of management options that could improve the status of the jaguar in Mexico.

Working group on habitat conservation and management

Members: Gerardo Carreón, Juan Carlos Faller, Lissette Leyequien, Iván Lira, Rurik List, Octavio Monroy, Carlos Navarro, Diego Woolrich, Heliot Zarza.

Identification of problems

1. Lack of a national strategy on the use and management of resources:
- Perverse incentives. In Quintana Roo, deforestation is required to claim government-owned land.
- Lack of coordination between government bodies regarding incentives and strategies. In some programs, the Ministry of Agriculture (Sagarpa) provides greater incentives for deforesting than those provided by the National Forestry Commission (Conafor) to conserve the forest.
- Lack of incentives for habitat conservation, including management practices –traditional or not– that maintain biodiversity and conserve the habitat.
- Different and contradictory approaches to management of resources in different properties.
- Lack of continuity of environmental projects and policies.
- Lack of knowledge about the jaguar.
- Inadequate legislation and weak law enforcement.

2. Habitat loss and fragmentation:
- High deforestation rates: increase in the demand of timber and non-timber resources, whose exploitation is poorly regulated.
- Conversion of land to agriculture, including extensive livestock farming.
- Growth of human settlements, including tourist resorts (Costa Maya), summer homes (between Sian Ka'an and the Bay of Chetumal) and villages.
- Tracks opened for the maintenance of electric transmission lines cause habitat fragmentation in a growing electrical network.
- In a strategic effort to fight forest fires, many kilometers of mechanized fire breaks have been opened in the north of Quintana Roo and Yucatan.

• Construction of new roads.
• Agricultural practices like slash and burn and the burning of grasslands are unregulated and hardly controlled, thus generating the loss of natural vegetation.

3. Changes in habitat quality:
• Poor management of extensive livestock farming contributes to conflicts between humans and large carnivores.
• Overgrazing reduces the availability of food for the natural prey of the jaguar.
• Poor management of agriculture and forests reduces the availability of prey and habitat quality.
• Changes in the prey base of the jaguar. Jaguar prey species are controlled to prevent damages to agriculture. Government programs promote monoculture.
• There is less water available in higher areas, so jaguars are using places that are closer to human settlements and livestock farming areas. Water pollution reduces the prey base of the jaguar.

4. Climate change is causing effects that are difficult to predict and affect jaguar habitat. The greater frequency and intensity of natural phenomena –hurricanes and droughts– triggers other negative effects, such as fires.

After identifying the problems, the group summarized the main ideas and drafted sentences that specifically define such problems. They are the following:

1. The absence of a national strategy on the use and management of natural resources causes a lack of coordination between government bodies, reflected in their incentives and strategies, and a lack of continuity of environmental projects and policies. Legislation is inadequate or not enforced.
2. Habitat loss and fragmentation is the result of the demand of forest resources, the expansion of the agricultural frontier, and the development of human settlements and infrastructure works.
3. The quality of jaguar habitat is affected by changes in land use, influenced by the following factors: poor management of agriculture and forests, poaching, and reduction in water availability in the short to long term.
4. Climate change is causing effects that are difficult to predict and can affect jaguar habitat. The greater frequency and intensity of natural phenomena –hurricanes and droughts– trigger fires and other negative effects for the resilience of the jaguar

Each of these problems was analyzed by the group, trying to find facts to support the statements and assumptions made (Table 1).

Table 1. Problems affecting the jaguar's conservation and its habitat

Problem 1. The absence of a national strategy on the use and management of natural resources causes a lack of coordination between government bodies, reflected in their incentives and strategies, and a lack of continuity of environmental projects and policies. Legislation is inadequate or not enforced.			
Sub-problem 1: Lack of coordination between incentives provided by government bodies			
Real information available	**Assumed information**	**Specific region affected**	**References**
Ministry of Agriculture provides greater incentives for deforesting than Forestry Commission to conserve the vegetation. Animal health authorities promote land clearing		National.	Regulations of agriculture and forestry authorities
Sub-problem 2: Perverse incentives			
Real information available	**Assumed information**	**Specific region affected**	**References**
Deforestation is required to claim government-owned land. Anticipated 6-year payment by livestock-farming development program led to purchase of more livestock where a conservation project was under way.		Quintana Roo; Lachixila, Oax. Possibly national scale.	Pers. comm. Carlos Navarro (from residents of San Pablo, Q. Roo); Pers. obs. Diego Woolrich.
Sub-problem 3: Lack of incentives for habitat conservation, including management practices – traditional or not – that maintain biodiversity and conserve the habitat			
Real information available	**Assumed information**	**Specific region affected**	**References**
Resources of agriculture and forestry authorities available for payments for ecosystem services relative to the surface that qualifies to receive them.		National.	Regulations of authorities in charge of agriculture, forestry and protected areas.
Sub-problem 4: Different and contradictory approaches to management of resources in different properties			
Real information available	**Assumed information**	**Specific region affected**	**References**
Naturalia has a property devoted to jaguar conservation, but its neighbor does not support conservation efforts.			Pers. comm. Craig Miller.
Sub-problem 5: Lack of continuity of environmental projects and policies.			
Real information available	**Assumed information**	**Specific region affected**	**References**
	Payments for ecosystem services must continue despite changes in government. Continuity in community development projects. Payment for timber products.	National. The three levels of government.	

Sub-problem 6. Inadequate legislation and lack of law enforcement			
Real information available	**Assumed information**	**Specific region affected**	**References**
In properties where forest exploitation is authorized, respect of regulations is not monitored, which reduces plant cover. There is no follow-up by the law enforcement arm for wildlife protection of most reports of jaguars hunted.		Estado de México. National.	Pers. comm. Octavio Monrroy; Pers. obs. Diego Woolrich, Carlos Navarro

Problem 2. Habitat loss and fragmentation is the result of the demand of forest resources, the growth of agriculture, and the development of human settlements and infrastructure works.			
Sub-problem 1. High deforestation rates: increase in the demand of timber and non-timber resources, whose exploitation is poorly regulated			
Real information available	**Assumed information**	**Specific region affected**	**References**
Habitat loss is the greatest threat to jaguar conservation. Clear cutting to harvest precious timber.		Yucatán. Chiapas. Chimalapas.	Jaguar PREP. Miranda 2000. Turner *et al.* 2002. Macera *et al*. 1997. *Chimalapas: la última oportunidad*. WWF.
Sub-problem 2. Conversion of land to agriculture, including extensive livestock farming			
Real information available	**Assumed information**	**Specific region affected**	**References**
Forest clearing for livestock farming. Technified coffee growing. Agriculture along corridors such as rivers (Bavispe).	The loss of plant cover caused by agricultural practices reduces the availability of refuges and potential prey for the jaguar.	Uxpanapa-Chimalapas-Ocote. Sierra Madre de Chiapas. Sonora.	*Tequio por los Chimalapas.* Pers. comm. Iván Lira. Pers. comm. Rurik List.
Sub-problem 3. Growth of human settlements, including tourist resorts, summer homes and villages			
Real information available	**Assumed information**	**Specific region affected**	**References**
The edge effect (population sink) increases with the growth of human settlements. Major tourist resorts: Costa Maya, Riviera Maya, Pinotepa-Huatulco, between Sian Ka'an and the Bay of Chetumal. Cities that support the Riviera Maya, Zoque Forest, Papaloapan River Basin. The spatial distribution of the jaguar and its prey is affected by human settlements in a radius of 6.5 km. This area is generally used for subsistence hunting as well.		National, on the coast. National. Campeche and Quintana Roo.	Ceballos 2006. Pers. comm. Rurik List. Pers. comm. Heliot Zarza.
Sub-problem 4. Tracks opened for the maintenance of electric transmission lines cause habitat fragmentation in a growing electrical network			
Real information available	**Assumed information**	**Specific region affected**	**References**
New electric transmission lines in Calakmul, la Ventosa. La Parota and El Cajón dams.	Tracks make access easier for hunters.	National.	
Sub-problem 5. New strategies to fight forest fires			
Real information available	**Assumed information**	**Specific region affected**	**References**

Hundreds of km of fire breaks after Hurricane Wilma.	Tracks make access easier for hunters.	North of Quintana Roo and Yucatán.	
Sub-problem 6. Construction of new roads			
Real information available	**Assumed information**	**Specific region affected**	**References**
Tracks make access easier for hunters and lead to the creation of new tracks. Transistmica highway. Cancún-Chetumal. Project of road linking Playa del Carmen and Chemax (Q. Roo-Yucatán). Chamela. The spatial distribution of the jaguar and its prey is affected by paved roads in a radius of 4.5 km.		National.	Ceballos *et al.*, 2006. Jiménez Maldonado p. 50. Pers. comm. Juan Carlos Faller. Pers. comm. Heliot Zarza.
Sub-problem 7. Agricultural practices like slash and burn and the burning of grasslands are unregulated and hardly controlled, thus generating the loss of natural vegetation			
Real information available	**Assumed information**	**Specific region affected**	**References**
More than 1000 ha burned in Nanchititla when a slash and burn fire got out of control. Many hectares were lost in Los Chimalapas in 2003. San Luis, El Naranjo, San Luis Potosí, during the preparation of the plots. Lacandona 1998. North of Quintana Roo and Yucatán 2006..		National.	Pers. comm. Octavio Rosas. Pers. comm. Iván Lira. Mendoza y Dirzo, 1999. Pers. comm. Juan Carlos Faller.

Problema 3. The quality of jaguar habitat is affected by poor management of agriculture and forests, poaching, and reduction in water availability in the short to long term			
Sub-problem 1: Poor management of extensive livestock farming leads to conflicts with predators			
Real information available	**Assumed information**	**Specific region affected**	**References**
Predation on livestock takes place mainly in areas where livestock is free all year round.		National.	Hoogestein *et al*., 1993. Jorgeson and Redford 1993. Jaguar PREP. Ceballos *et al*., 2006.
Sub-problem 2: Overgrazing reduces the availability of food for natural jaguar prey			
Real information available	**Assumed information**	**Specific region affected**	**References**
In Sierra de Vallejo very few plants in the forest is not overgrazed. In Yucatán there is overgrazing in coastal forests, mainly in the ecoregion Los Petenes-Celestún-El Palmar, and buffer zones of the protected areas Dzilam and Ría Lagartos. In Sonora, areas occupied by the jaguar are overgrazed.		National.	Pers. com. Rodrigo Núñez. Pers. com. Juan Carlos Faller.

Sub-problem 3: Poor management of agriculture and forests reduces prey and habitat quality			
Real information available	**Assumed information**	**Specific region affected**	**References**
More information is needed.			
Sub-problem 4: Changes in the prey base of the jaguar.			
Real information available	**Assumed information**	**Specific region affected**	**References**
Jaguar prey species are controlled to prevent damages to agriculture. Government programs promote monoculture.		National.	
Sub-problem 5: Poaching and subsistence hunting reduces prey availability			
Real information available	**Assumed information**	**Specific region affected**	**References**
The main prey of jaguar are also the animals most hunted by local people.	When no food is available in the forest, jaguars tend to predate on livestock.		Amin, 2004. Naranjo, 2000. Pers. comm. Sofie Calme.
Sub-problem 6: Reduction of water available			
Real information available	**Assumed information**	**Specific region affected**	**References**
This is pushing jaguars towards places closer to human settlements and livestock farming areas.	Oil spills in the region of Coatzacoalcos may affect jaguar prey.		Jaguar PREP. Pers. comm Lisette Leyequién.

Problem 4. Climate change is causing effects that are difficult to predict and may affect jaguar habitat. The greater frequency and intensity of natural phenomena –hurricanes and droughts– trigger fires and other effects that may be negative for the jaguar			
Sub-problem 1: Climate change is causing effects that are difficult to predict and may affect jagiar habitat			
Real information available	**Assumed information**	**Specific region affected**	**References**
The increase in the frequency and intensity of natural phenomena (hurricanes and droughts) causes fires and other factors of change.	Fires and droughts can have negative effects for jaguars.	National.	

The group developed specific targets and actions to tackle each of these problems, including institutions or people in charge, timeframes, partners and budget (Table 2).

Table 2. Development of targets and actions for habitat conservation and management

Problem 1. The absence of a national strategy on the use and management of natural resources causes a lack of coordination between government bodies, reflected in their incentives and strategies, and a lack of continuity of projects. Legislation is inadequate or not enforced.

Target	Actions	Person/institution in charge	Period
1.1. Put an end to contradictory and detrimental incentives for conservation, and increase implementation of effective incentives. Short term.	1.1.1 Produce a list of incentives that contribute to the conservation of the jaguar and its habitat or are detrimental to it, including recommendations. This should be done in the following federal bodies: Conanp, Sagarpa, Conafor, SCT, CFE, Pemex, SE, Secon, CNA, SHCP, Sedesol, Sectur, and others, as well as their state and municipal equivalents, as appropriate. The document shall be reviewed and endorsed by the Technical Advisory Subcommittee and promoted in the respective government bodies. 1.1.2 Promote the adoption of the recommendations in the government bodies targeted.	Erik Saracho and Technical Advisory Subcommittee	6 months. 12 months.
1.2 Ensure coordination between government bodies that have some impact on the conservation or disturbance of jaguar populations or habitat. Short term.	1.2.1 Apply for participation in periodic meetings with representatives of government bodies that have an influence on the conservation of the jaguar or its habitat to report on actions, solve conflicts, or define responsibilities.	Technical Advisory Subcommittee, Conanp. Representative of each priority region for jaguar conservation.	Permanent.
1.3 Implementation of traditional and non-traditional practices that maintain biodiversity in priority areas for jaguar conservation. Short term.	1.3.1 Prepare a list of practices that contribute to the conservation of the jaguar and its habitat or are detrimental to it, including recommendations.	Diego Woolrich (Pueblo Jaguar A.C.).	3 months.
1.4 A scheme to allocate financial resources in priority areas. Short term.	1.4.1 Prepare a guiding document for the Jaguar Subcommittee to allocate and prioritize resources.	Rodrigo A. Medellín. Jaguar Subcommittee.	3 months.
1.5 A strategy promoting environmental policies that contribute to the conservation of the jaguar and its habitat. Medium term.	1.5.1 Identify environmental policies that contribute to the conservation of the jaguar and its habitat. 1.5.2 Highlight the importance of such environmental policies in the conservation of the jaguar and its habitat as a focal species to the different government bodies in their respective programs.	Conanp, Technical Advisory Subcommittee.	24 months.
1.6 Continuity of environmental projects and policies promoting the conservation of the jaguar and its habitat. Short, medium and long term.	1.6.1 Produce a document with a list of environmental projects and policies promoting jaguar conservation.	Conanp, Technical Advisory Subcommittee.	12 months.

Problem 2. Habitat loss and fragmentation is the result of the demand of forest resources, the expansion of the agricultural frontier, and the development of human settlements and infrastructure works			
Target	**Actions**	**Person/institution in charge**	**Period**
2.1 Monitor the rate of change of forest cover in key jaguar areas.	2.1.1 Assess the rate of change and fragmentation of forest cover every 5 years in key jaguar areas at a national scale with the 2000-2001 National Forest Inventory (and subsequent forest inventories), series 3 INEGI.	Heliot Zarza.	6 months every 5 years.
2.2. A monitoring strategy for an appropriate exploitation of natural resources and productive practices. Short term.	2.2.1 Prepare a document with the monitoring strategy for an appropriate exploitation of natural resources and productive practices.	Patricia Oropeza - Conanp.	9 months.
2.3 Implementation of mitigation and compensation measures for infrastructure works, roads and land use conversion. Short term.	2.3.1 Review the environmental impact statements of infrastructure projects in priority areas for jaguar conservation to learn about the mitigation and compensation measures required by the Ministry of the Environment (Semarnat), and ensure they are implemented to benefit jaguar habitat. 2.3.2 Make a recommendation asking Semarnat to include priority areas for jaguar conservation as a basic criterion to apply state mitigation funds.	Secretary of the Jaguar Technical Subcommittee.	Permanent. 6 months.
Problem 3. The quality of jaguar habitat is affected by poor management of agriculture and forests, poaching, and reduction in water availability in the short to long term			
Target	**Actions**	**Person/institution in charge**	**Period**
3.1 Environmentally-friendly economic alternatives in important areas for the conservation of the jaguar and its habitat. Medium term.	3.1.1 Prepare a regional guiding document listing, analyzing and certifying alternative productive activities that are compatible with the conservation of the jaguar and its habitat. 3.1.2 Develop a project to certify and market products obtained through jaguar-friendly techniques, giving an added value to the products.	A representative of each priority region for jaguar conservation. Lisette Leyequien, Jaguar Technical Subcommittee.	18 months. 2 years.
3.2 Participatory planning workshops focused on habitat conservation in communities in priority jaguar areas. Short and mid term.	3.2.1 Organize participatory workshops in priority areas for the conservation of the jaguar and its habitat.	A representative of each working group.	24 months.
Problem 4. Climate change is causing effects that are difficult to predict and can affect jaguar habitat. The greater frequency and intensity of natural phenomena (hurricanes and droughts) trigger fires and other negative effects for the resilience of the jaguar			
Target	**Actions**	**Person/institution in charge**	**Period**
4.1 Information available on the effect of climate change in priority jaguar areas.	4.1.1 Generate information on the effect of climate change on the distribution of the jaguar and its habitat, modeling changes in natural vegetation in a climate change scenario and assessing the effect of fires caused by hurricanes in populations of jaguar prey. Assess the effect of droughts on jaguar reproductive success in arid areas of its range.	Cuauhtémoc Chávez and Heliot Zarza.	4 years.

Working group on the interrelation between the jaguar and society

Members: Alfonso Aquino, Rosa María Balvanera, Gerardo Ceballos, Rodrigo Núñez, Patricia Oropeza, Antonio Rivera, Erik Saracho.

This group focused on the different situations leading to conflicts between jaguars and humans. Conflicts can be direct –when humans eliminate jaguar individuals or populations –or indirect– when anthropogenic activities affect jaguar populations indirectly through habitat changes or hunting of natural jaguar prey, for example; they can also be due to the lack of clear policies for the conservation of the species and its habitat.

Identification of problems

The working group identified 6 main problems that include secondary problems, most of which are interrelated and converge into the main problem.

1. Habitat loss:
• Agriculture
• Unsustainable tourism regulation
• Construction of hydroelectric dams
• Land use conflicts, extensive livestock farming
• Invasion of priority areas
• Extraction of forest resources
• Forest fires

2. Habitat fragmentation:
• Roads and infrastructure
• Electric transmission lines
• Changes in land use
• Major tourist resorts
• Human settlements
• Land tenure problems

3. Elimination of jaguar populations:
• Illegal capture and poaching (trapping, poisoning, capture, etc.)
• Predation on livestock by jaguars
• Diseases

4. Conservation policies:
• Contradictory public policies (laws and regulations)
• Lack of clarity in objectives put forward by scientists

• Lack of financial support and budget items
• The jaguar and its habitat are not a priority in public policies
• Lack of appropriate sustainable productive projects
• Lack of ambitious jaguar conservation objectives
• Lack of greater strength in management of protected areas and priority conservation areas
• Lack of appropriate implementation of the environmental land planning regulations
• Fragmentation of public policies

5. Social (environmental) management
• Lack of environmental education
• Low social participation
• Lack of involvement and empowerment of communities concerning the use of resources
• Lack of markets

6. Scientific and academic management:
• Lack of clear national objectives for the conservation of the jaguar and its habitat.

By grouping and consolidating each of the items developed, the group managed to produce sentences summarizing problems in the interaction between jaguars and society. They are the following:

1. Poorly planned human growth and development activities lead to jaguar habitat loss and fragmentation.
2. Conflict with humans and anthropogenic activities leads to loss of individuals and populations of jaguar and its prey.
3. The lack of well-developed public policies has a negative impact on the conservation of the jaguar and its habitat.
4. There is a lack of empowerment and involvement of society in general –rural and urban dwellers, scholars, organized civil society, etc.– to successfully conserve the jaguar and its habitat.
5. The lack of clear national objectives for the conservation of the jaguar and its habitat has a negative impact on the long-term survival of jaguar populations in Mexico.

After defining the existing problems between jaguars and their conservation, and Mexican society and jaguar conservation, the group identified the facts supporting such statements. This clarified a number of assumptions (Table 3).

Table 3. Analysis of problems in the interrelation between jaguars and society				
Problem 1. Poorly planned human growth and development activities lead to jaguar habitat loss and fragmentation				
Real information available	**Assumed information**	**Information needed**	**Specific region affected**	**References**
Tomatlán Irrigation District, Jalisco (50,000 ha). This is a flat area of semi-evergreen forest where, according to reports, jaguars used to be abundant but disappeared in less than 30 years.			Coast of Jalisco.	Miranda, 1998.
El Cajón dam, Santa María del Oro, Nayarit (Manuel Rodríguez Alcaine). The environmental impact statement (MIA) omitted the presence of jaguars and pumas and did not consider mitigation measures. As a consequence, the area of jaguar dens was destroyed. (200 km², 20,000 ha, a wall 189 m high).			Santa Maria del Oro, Nayarit.	MIA CFE, 2005.
Desarrollo Turístico Riviera Maya Fonatur developed the area from Cancún to Xcalak, destroying most of the forest and mangroves, causing a considerable habitat reduction, and increasing the effects of hurricanes. A two-lane road was built, dividing the forest of the region.			Costa Maya.	Government Plan. State of Quintana Roo, 2000-2005. MIA POET Región PY.
The road from Sayulita to Punta Mita (25 km) was built without an environmental impact statement, parallel to the boundary of the Sierra de Vallejo protected area, where jaguars occur.			South of Nayarit, Bahía de Banderas (2005).	Legal-administrative document. Profepa.
Problem 2. Conflict with humans and anthropogenic activities leads to loss of individuals and populations of jaguar and its prey.				
Real information available	**Assumed information**	**Information needed**	**Specific region affected**	**References**
Seizure of 23 jaguar skins in Chetumal (2001).	The loss of plant cover caused by agricultural practices reduces the availability of refuges and potential prey for the jaguar.		Chetumal, Quintana Roo.	Ceballos *et al.,* 2005.
Poaching of 10 jaguars in two communities (Katunilkin and Francisco May).			Northern Quintana Roo (Lázaro Cárdenas and continental Isla Mujeres, 2004).	Pers. comm. Carlos Navarro.
Seizure of 46 live jaguars in Mexico (10 states).			10 states (Yucatan Peninsula, southeastern and western Mexico) 2000-2005.	Official Report. Profepa, 2005.
12 jaguars hunted (2004-2005)			*Ejidos* Nuevo Becan and 20 de Noviembre.	Pers. comm. Antonio Rivera.

Problem 3. The lack of well-developed public policies has a negative impact on the conservation of the jaguar and its habitat				
Real information available	**Assumed information**	**Information needed**	**Specific region affected**	**References**
The abrogation of legislation (NOM-22) protecting mangroves has led to the loss of important areas with jaguar populations..			Mangroves forming an ecological corridor from Cancún to Xcalac (2004-2006).	Complaint of Centro Mexicano de Derecho Ambiental to Profepa, the law enforcement body. Faller *et al*., 2004-2005.
Incentives of the Ministry of Agriculture to transform forests into grassland and cropland.		National program for the creation of grasslands, PAPIR, Alianza para el Campo, Procampo, Progan, Cotecoca, Sagarpa.	Calakmul Biosphere Reserve and neighboring areas.	Pers. comm. Gerardo Ceballos.
Development of infrastructure in protected area by CFE, SCT and Pemex.			The Arriaga-Ocozocoautla freeway crosses La Sepultura Biosphere Reserve, Chiapas, 2003-2007.	Pers. comm. Epigmenio Cruz Aldan.
Contradictions between the acts establishing the Ministries Agriculture and the Environment.		Mexican Official Journal and acts establishing both ministries.	National.	Mexican Official Journal. Sustainable development as a cross-cutting issue in the agenda of public policies. Sagarpa, Semarnat.
Construction of electric transmission lines between Tecnosique and Lacanja.			Sierra de la Corolita, municipality of Ocosingo, Chiapas, 2003-2004.	Pers. comm. Epigmenio Cruz Aldan.

Problem 4. There is a lack of empowerment and involvement of society in general – rural and urban dwellers, scholars, organized civil society, etc. – to successfully conserve the jaguar and its habitat				
Real information available	**Assumed information**	**Information needed**	**Specific region affected**	**References**
In Sierra de Vallejo protected area there is a lack of environmental education at all levels. No sustainable development programs are in place.			Sierra de Vallejo, Nayarit.	Previous study justifying the designation the protected area, 2004. (Saracho and Núñez).
Global problem of the capture of a jaguar (Jaguar de la Luz). Region of Lachixila, municipality of Ayotzintepec, Oaxaca.			Region of Lachixila, municipality of Ayotzintepec, Oaxaca. 2004-2006.	Chronological account of the event (Pueblo Jaguar A.C.), Legal-administrative document. Profepa, 2004- 2006.

The Community Watch strategy has no social recognition due to lack of awareness (environmental education) in the community.			Cabo Corrientes, Jalisco, 2006.	Reports of the Profepa team, Jalisco, 2006.
The community of Ursulo Galván allocated 2000 ha to a Jaguar Sanctuary, but there has not been enough coordination, social participation or funding to implement it.			Sierra de Vallejo, 2004-2006 Nayarit.	La Voz de la Sierra, community newspaper. Previous study justifying the creation of the protected area, 2004.
Problem 5. Lack of clear national objectives for the conservation of the jaguar and its habitat				
Real information available	**Assumed information**	**Information needed**	**Specific region affected**	**References**
In a meeting with senior officials of the sector, it was observed that the number of jaguars in Mexico was unknown (2004). This number is still not known.			National	Pers. comm. Erik Saracho, taken from *Antecedentes para la Declaratoria del Año del Jaguar* (2004).
The core area of Calakmul Biosphere Reserve should be redefined according to the habitat preferences of the jaguar as an indicator species.			Calakmul Biosphere Reserve.	Annual Operational Plan of Calakmul Reserve.
Regarding El Cajón dam, the *Comité Consultivo* consulted the Subcommittee of the jaguar PREP on a diagnosis of damage to the area but got no answer.			Municipality of Yesca, Nayarit.	Minutes of the *Núcleo Nayarit del Consejo Consultivo Sustentable.*
In the framework of the Year of the Jaguar, the minimum viable population size for the jaguar was not known at the Symposium on the Jaguar in the 21st Century.			National.	Minutes of the Symposium on the Jaguar in the 21st Century, October 2005.

After establishing the facts and assumptions on the problems identified by the group, the problems were prioritized on the basis of the most direct cause affecting jaguar conservation. The problems are classified below in order of importance:

1. Conflict with humans and anthropogenic activities leads to loss of individuals and populations of jaguar and its prey.
2. The lack of clear national objectives for the conservation of the jaguar and its habitat has a negative impact on the long-term survival of jaguar populations in Mexico.
3. The lack of well-developed public policies has a negative impact on the jaguar's conservation and its habitat.
4. Poorly planned human growth and development activities lead to jaguar habitat loss and fragmentation.

5. There is a lack of empowerment and involvement of society in general –rural and urban dwellers, scholars, organized civil society, etc.– to successfully conserve jaguar and its habitat.

After identifying the problems, supporting facts and assumptions, the group developed specific targets and actions to mitigate these threats in the short and long term.

The following is a visual summary of targets and actions that should be implemented for each of the problems identified.

Table 4. Targets and actions for the interrelation between the jaguar and society			
Problem 1. Conflict with humans and anthropogenic activities leads to loss of individuals and populations of jaguar and its prey.			
Target	**Actions**	**Person/institution in charge**	**Period**
1.1 A national directory of hunters and guides (file and identification).	1.1.1 Develop a national database with the help of Semarnat, Sectur and Profepa.	Rurik List, Heliot Zarza.	2007.
1.2 Coordination with and between government authorities and the general public to ensure the protection of the jaguar and law enforcement.	1.2.1 Promote an agreement between Sagarpa, Semarnat, Profepa, (PGR), state and municipal authorities to deal with cases related to jaguar conservation expediently (1 document).	Gerardo Ceballos, Rodrigo A. Medellín, Erik Saracho, Alfonso Aquino.	2007.
1.3 Identify critical areas with jaguar-livestock conflicts in Mexico.	1.3.1 Produce a database with the help of *Confederación Nacional Ganadera*, Sagarpa and *Confederación Nacional Campesina* to identify areas with jaguar-livestock conflict. 1.3.2 Design appropriate strategies for each of the priority areas for jaguar conservation (2 documents).	Alfonso Aquino, Dino Rodríguez, Heliot Zarza.	March 2007.
1.4 Reduce illegal hunting of jaguars in Mexico. Level c: opportunism (the whole country) 1% of the jaguar population.			
Level b: local sport hunting (places with jaguars near urban areas) 3% of the jaguar population. Level a: national and international sport hunting (Campeche, Tamaulipas, Jalisco, Guerrero) 5-10% of the jaguar population.	1.4.1 Identify critical areas for jaguar hunting in Mexico (1 document). 1.4.2 Produce a database with Semarnat, Profepa, Sedena, PGR (1 database). 1.4.3 Design strategies to deal with each case of hunting identified (subsistence, opportunistic, sport and professional hunters), contact the people appointed by the ministers of Sedena and Semarnat to analyze the situation and request their cooperation to eliminate jaguar hunting (1 document).	Antonio Rivera, Erik Saracho.	July 2007.

Problem 2. Lack of clear scientific objectives for jaguar conservation and its habitat			
Target	**Actions**	**Person/institution in charge**	**Period**
2.1 Clear and agreed scientific objectives that benefit priority areas for jaguar conservation.	2.1.1 Prioritize scientific information and coordinate management.	Gerardo Ceballos Rodrigo Núñez Cuauhtemoc Chávez Heliot Zarza Rurik List.	January to July 2007.
	2.1.2 Make a national assessment of jaguar distribution and abundance, its habitat and its prey (1 meeting).	Gerardo Ceballos Rodrigo Núñez Cuauhtémoc Chávez Heliot Zarza Rurik List.	November 2009.
	2.1.3 Determine the minimum viable population size for the jaguar in Mexico (1 document).	Gerardo Ceballos Rodrigo Núñez Cuauhtémoc Chávez Heliot Zarza Rurik List.	November 2009.
	2.1.4 Give priority to the following research areas: effect of diseases, behavioral aspects, genetics in population dynamics, and assessment of livestock management techniques to reduce conflicts with jaguars (1 document).	Gerardo Ceballos Rodrigo Núñez Cuauhtémoc Chávez Heliot Zarza Rurik List.	November 2006 to November 2008.
	2.1.5 Manage and generate financial and human resources for scientific research on the jaguar.	Gerardo Ceballos Rodrigo Núñez Cuauhtémoc Chávez Heliot Zarza Rurik List.	Permanent.
2.2 Scientific information on jaguar available to the different sectors of society in an appropriate language.	2.2.1 Adapt and disseminate scientific information on the jaguar to the different sectors of society in a clear language for greater understanding, awareness and participation (documents).	Erik Saracho Rosa Ma. Balvanera Dino Rodríguez.	Permanent.
2.3 Funding for research and conservation of jaguar and its habitat.	2.3.1 Manage the Mixed Semarnat-Conacyt Fund for studies on jaguar.	Gerardo Ceballos.	January 2007.
2.4 A scheme to allocate funding in priority areas. Short term.	2.4.1 Prepare a guiding document for resource allocation and prioritization by the Jaguar Subcommittee.	Rodrigo A. Medellín and Subcomité.	3 months.
2.5 A strategy promoting environmental policies that contribute to conserving the jaguar and its habitat. Medium term.	2.5.1 Identify environmental policies that contribute to conserving the jaguar and its habitat. 2.5.2 Highlight the importance of such policies in conserving the jaguar as a focal species and its habitat to the authorities in their respective programs.		
2.6 Continuity of environmental projects and policies promoting the conservation of jaguar and its habitat. Short, medium and long term.			6 months

Problem 3. The lack of well-developed public policies has a negative impact on the conservation of the jaguar and its habitat			
Target	**Actions**	**Person/institution in charge**	**Period**
3.1 Make jaguar conservation a PRIORITY for the Federal Government 2007-2012 National Development Plan, especially Semarnat.	3.1.1 Prepare an executive summary of the recommendations issued by the PHVA workshop and provide it to Semarnat.	Gerardo Ceballos Rodrigo Núñez Rodrigo A. Medellín Rurik List Antonio Rivera.	January 2007.
3.2 Detect inconsistencies between the different laws or regulations related to jaguar conservation in the different ministries or other levels of government.	3.2.1 Set up a group and a program to review legislation related to the conservation of the jaguar and its habitat (1 program).	Alfonso Aquino Gerardo Ceballos Rodrigo A. Medellín	April 2007.
3.3 Strengthen the Technical Advisory Subcommittee of the Jaguar PREP.	3.3.1 Hold a meeting every six months to deal with issues related to the PREP (2 meetings a year).	Carlos Manterola Rodrigo Núñez Erik Saracho Gerardo Ceballos.	June and November 2007.
3.4 Minimize the impacts caused by programs that are detrimental to priority areas for jaguar conservation.	3.4.1 Identify programs that are detrimental to the conservation of priority areas (1 list of programs).	Alfonso Aquino Erik Saracho.	April 2007.
Problem 4. Poorly planned human growth and development activities lead to jaguar habitat loss and fragmentation			
Target	**Actions**	**Person/institution in charge**	**Period**
4.1 Synergy between institutions to minimize pressure on jaguar habitat.	4.1.1.Establish agreements between Semarnat-Sectur, Semarnat-CFE, Semarnat-Pemex, Semarnat-SCT to review the environmental impact assessments of their development projects in detail in priority areas for the jaguar (4 documents). 4.1.2 Promote such agreements and support Semarnat in this endeavor.	Gerardo Ceballos Alfonso Aquino Dino Rodríguez. Gerardo Ceballos Alfonso Aquino Dino Rodríguez.	January to July 2007. January to July 2007

Report of the group on population biology and modelling

Members: Roberto Aguilar, Marcela Araiza, Danae Azuara, Cuauhtémoc Chávez, Epigmenio Cruz, Juan Cornejo, Mariana Díaz, Melissa López, Rodrigo A. Medellín and William Van Pelt.

Introduction

VORTEX is a simulation program designed to analyze population viability. We used it to model the interaction between a number of parameters of the population and the natural history of the jaguar (*Panthera onca*). It conducts a stochastic analysis to explore which demographic parameters are most sensitive to different management options, and test the effects of different habitat management scenarios.

VORTEX runs Monte Carlo simulations of the effects of deterministic, demographic and environmental forces and stochastic genetic effects on wild populations. VORTEX models population dynamics as discrete sequential events (e.g., births, deaths, sex ratio of offspring, catastrophes, etc.) that happen according to defined probabilities. The probability of an event is modeled as a constant or random variable with specific distributions. The program simulates a population experiencing the events that describe the typical life cycle of diploid organisms with sexual reproduction.

VORTEX is not aimed at providing absolute responses; it stochastically projects interactions between the different input parameters of the model and the random processes that happen in nature. The interpretation of the results depends on our knowledge of the biology of the jaguar, the environmental conditions that affect the species, and possible future changes in these conditions. For a more detailed explanation of VORTEX and its use in population viability assessment, consult Miller and Lacy (1999) and Lacy (2000). With the demographic data available, we decided to perform the following tasks:

- Build a generic (basic) model of the jaguar population to study the main demographic factors that affect the population.
- Build a model of the jaguar population for six priority conservation areas for the species in Mexico: Calakmul-Maya Forest, Zoque Forest, Jalisco-Nayarit, Sonora, Tamaulipas, and Ría Lagartos (Ceballos *et al.*, 2005).
- Estimate the minimum viable population size for each region.
- Determine the population trend and probability of extinction of each of the populations in present conditions.
- Explore various management options such as the increase or decrease of the effects anthropogenic activities.

It is important to note that unfortunately there is not enough information available on reproductive and survival rates of wild populations to develop accurate population models. Therefore, the models cannot be used to make absolute and accurate predictions on the future of the population. Yet, the models can be used to study the relative response of the jaguar population to demographic changes. Such changes can reflect our own uncertainty on the values of parameters being measured in the field, or represent the results of human activities, such as habitat or management changes. We can study the impact of this uncertainty on the behavior of the model by means of a sensitivity analysis. This information can be used to set research and management priorities.

Input parameters for the generic model

To build the generic model, we used the best estimations of demographic parameters available for the jaguar population. They were those of Calakmul Biosphere Reserve, the region that has been studied the most. In this model, the population was considered to be free of anthropogenic effects. All the simulations were made with VORTEX version 9.61.

Number of iterations: 500
500 independent iterations were run for each scenario.

Number of years: 100
The jaguar is considered to have a life expectancy of 10 years in the wild. The population was modeled for 100 years – about 15 generations – to observe long-term population trends.

Definition of extinction: Only one sex remains
In the model, the population is considered extinct when no individuals or only individuals of the same sex remain.

Definition of viability: PE<10% in 100 years
The population was considered viable if it had a probability of extinction (PE) lower than 10% in the 100 years of the simulation.

Mating system: Polygamous
Jaguars are polygamous; males have a relatively broad home range where they can meet several females. This area can be visited several times in a year.

Age at first reproduction: 3 years (females), 4 years (males)
VORTEX considers age at first reproduction to be the age at which the first litter is born, which does not necessarily coincide with sexual maturity. Jaguar males and females reach sexual maturity at about 3 years (Chávez 2006; Eizirik *et al.*, 2002; Quigley and Crawshaw, 2002). Yet, males do not usually reproduce until the age of 4, when they reach the necessary body size to establish themselves in a territory and defend it. Females reproduce as soon as they reach sexual maturity (C. Chávez, pers. obs.).

Age of reproductive senescence: 10
VORTEX assumes that the animals can reproduce (at a normal rate) throughout their adult life and does not consider reproductive senescence. Individuals are eliminated

from the model once they reach their maximum reproductive age. This is probably quite realistic in jaguars. It was estimated according to maximum longevity in the wild-10 years (Ceballos *et al.*, 2005; Chávez *et al.*, 2005; Crawshaw, 2002).

Maximum number of offspring per year: 3

The size of jaguar litters is 1-3 cubs (Ceballos *et al.*, 2005; Chávez *et al.*, 2005; Quigley and Crawshaw, 2002;). Mean litter size was 1.7 individuals, with the following distribution: 1 cub - 45%, 2 cubs - 40% and 3 cubs - 15%.

Sex ratio at birth: 1:1

The sex ratio at birth is assumed to be 50%, as there is no evidence suggesting an unbalanced sex ratio.

Males in the breeding group: 45%

Only 45% of adult males were considered to be potential breeders, because not all males have access to a female. Older males with established home ranges are the ones that usually contribute to the gene pool of the offspring (Chávez, 2010).

Breeding adult females: Density dependent

Considering that competition for prey and mates increases with population density, we used a density-dependent model in which the ratio of breeding adult females depends on population density. At population sizes below 80% of K, half of the adult females breed, and at sizes above 80% of K, the ratio of breeding adult females drops from 50 to 30%. We used the formula shown in Figure 1 to introduce these data into the model.

Mortality: Offspring mortality is estimated to be high in the first months of life and at weaning and to decrease between the first and second year of life, when females accompany their cubs. Male mortality is estimated to be higher than female mortality in the dispersal period –2 to 4 year– because males disperse more, as they are less accepted by others with established home ranges. Adult males and females are considered to have lower mortality because they have established their territory.

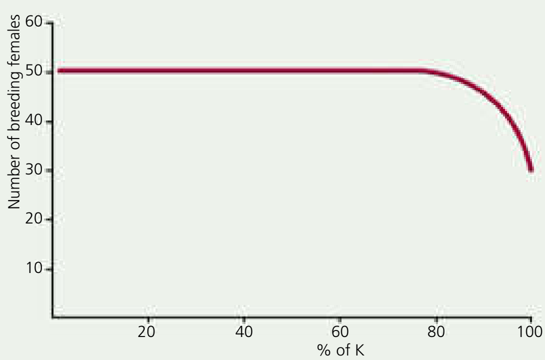


Figure 1. Equation used in the basic model to estimate density dependence in the % of breeding females.

% Breeding adult females = (50-((50-20)*((N/K)^16))).

Yet, mortality in both sexes increases between 8 and 10 years because of age-related reasons, such as teeth problems and injuries caused by fights (C. Chávez, G. Ceballos, pers. comm.). To introduce these data into the model, we used the formula: Mortality from class 4 onwards = 10 + ((A>8)*5*(A-8)) for females and = 10 + ((A>8)*3.25*(A-8)) for males.

Correlation between the environmental variable (EV) and the reproductive and survival rates: yes

Environmental variation is the annual variation in reproduction and survival caused by random variation in environmental conditions. We consider that environmental variation does not only affect jaguars directly but also prey populations, which in turn has an impact on jaguar reproduction and survival.

Inbreeding depression: yes

Inbreeding is considered to have a major effect on reproduction and survival of populations, especially small ones. VORTEX makes it possible to model these detrimental effects, such as the reduction in offspring survival in the first year of life. The inbreeding effect was modeled as 3.14 lethal equivalents, the mean value estimated in the study of captive populations of 40 mammal species (Ralls *et al.*, 1988), with 50% (when N≤1000) or 100% (when N>1000) of the inbreeding effect due to recessive lethal alleles.

Catastrophes: yes (2)

Catastrophes are singular environmental events that do not correspond to normal environmental variation and can affect the reproduction and/or survival of the species. Natural catastrophes include hurricanes, floods, diseases, droughts or similar events. Such events can be modeled by VORTEX assigning an annual probability of occurrence and a couple of severity factors, describing their impact on mortality (in all age classes and sexes) and the proportion of females that breed successfully in a given year. The jaguar population of Calakmul is considered to be exposed to two types of catastrophes: hurricanes and droughts. A frequency of 10% was determined for hurricanes, with a 25% reduction in reproduction and a 5% increase in mortality. A frequency of 10% was also determined for droughts, with a 25% reduction in reproduction.

Initial population size (N): 650

The population of Calakmul was estimated to contain 650 individuals, considering that one individual/15 km^2 is reported in this area (Ceballos *et al.*, 2002, 2005, Chávez *et al.*, 2005; this volume) and that the surface of the reserve is 975,000 ha. In the absence of specific data, the population was considered to have a stable age distribution.

Carrying capacity (K): 700

The carrying capacity (K) of a given habitat defines the maximum population size the habitat can support, above which mortality is randomly distributed in all age classes to bring the population back to its K value. A conservative value of 700 individuals was randomly established for the Calakmul population. Since reproduction is considered to be density dependent, the population is expected to self-regulate before reaching K.

Harvest and supplementation: not included (Table 5)

Results of the generic model

The basic model represents the information available and the best estimates of participants in the workshop on the biology of jaguar in Calakmul. Future population projections should be interpreted with caution, as they depend on the accuracy of the input parameters used. The model should be reviewed and updated as better data become available.

Deterministic values

The demographic rates –reproduction and mortality– included in the basic model can be used to calculate the deterministic characteristics of the population modeled. These values reflect the biology of the population in the absence of stochastic fluctuations –either demographic or due to environmental variation– , inbreeding depression, mate limitations, and immigration/emigration. These values should be examined to determine whether they seem realistic for the species and population the model is applied to. The values introduced in the jaguar generic model show a deterministic growth rate (rdet) of 0.021 (λ = 1.022). This represents a potential annual growth rate of about 2%. Generation time (mean age at first reproduction) is 6.4 for males and 5.8 for females. Adult sex ratio is 0.48 males per female. Very

Table 5. Input demographic parameters for jaguar VORTEX generic model

Input parameter	Value in generic model
Mating system	Polygamous
Age at first reproduction (/)	4/3
Age of reproductive senescence ♂ ♀	10
Inbreeding depression	I (3.14 lethal equivalents)
Maximum number of offspring per year	3
Mean litter size	1.7
Adult males in breeding group	45%
Breeding adult females	30-50% (Density dependent)
Male mortality (class 0-1, 1-2, 2-3, 3-4, 4+)	(25,20,35,25, =10+((A>8)*(6.5)/2*(A-8)))
Female mortality (class 0-1, 1-2, 2-3, 3+)	(25,20,10=10+((A>8)*5*(A-8)))
Catastrophes	2 (hurricanes and droughts)
Sex ratio at birth	1:1
Initial population size	650
Carrying capacity	700
Number of iterations and number of years	500 iterations, 100 years

few individuals reach the age of 10 years (3.1% of the population). In general, these characteristics of the population seem realistic for jaguars in Calakmul.

Stochastic values

The results of the generic model project a population that maintains its numbers and 97% of its original genetic diversity in 100 years. The probability of extinction of the population in this period is 0%, and the rate of stochastic growth (rstoch) is 0.005, so the population remains practically stable. Figure 2 shows the average population size over 100 years. The variation observed reflects annual uncertainty in reproduction and mortality rates due to the intrinsic stochasticity of the model.

Sensitivity analysis

In the discussion on the input data for the model, it became evident that some demographic characteristics had been estimated with a high degree of uncertainty. We carried out a sensitivity analysis by building additional models to the generic one and studying the potential effect on the results to try to identify research and/or management priorities. In each model, we changed one of the parameters in a fixed interval of proportional values, leaving the remaining ones unchanged, as in the generic model. This allowed us to compare the impact of each parameter on the population (Table 6).

The generic model is most sensitive to parameters with the greatest changes in the stochastic growth rate across the range of proportional parameters.

According to the results of the analysis of sensitivity of the reproductive parameters shown in Figure 3, we can conclude that the generic model is not very sensitive

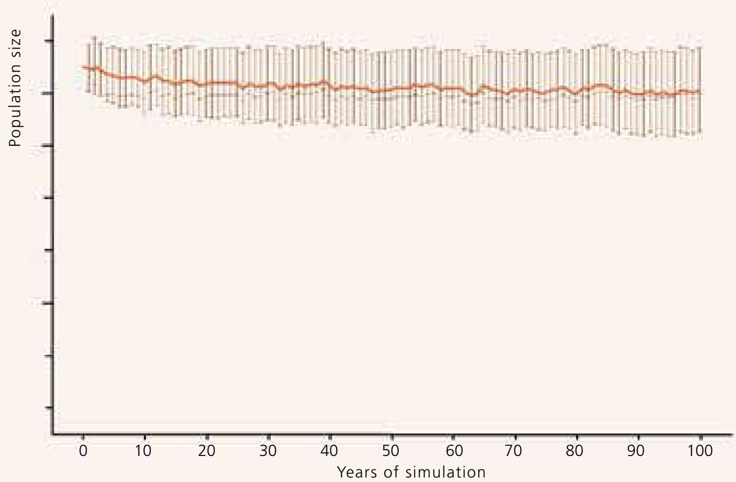


Figure 2. 100-year projection of population size (N ± DS), assuming that the population is free of anthropogenic impacts

to variations in the percentage of males in the gene pool. Yet, it shows significant variation depending on litter size, and is especially sensitive to an increase in the percentage of reproductive females and a decrease in maximum reproductive age.

As regards the sensitivity of mortality parameters, shown in Figure 4, there was high sensitivity to changes in infant mortality and especially to an increase in the mortality of adult females. Changes in the mortality of adult males did not have a significant effect on the stochastic growth rate of the population.

Risk analysis I: minimum population size and carrying capacity

Depending on the biology of species and their threats, it is possible to define a minimum viable population (MVP) size below which the probability of extinction of the population exceeds a given threshold over a given period of time.

We ran several scenarios based on the generic model, changing the initial number (No) and the carrying capacity (No = K). It was determined that, for initial sizes of less than 100 individuals, the probability of extinction in 100 years is greater than 10% and therefore the population is not considered viable according to the parameters established initially.

Table 6. Values used in the models of the sensitivity analysis.
100% corresponds to the generic model

	75%	87.5%	100%	112.5%	125%
% of breeding females	37.5	43.7	50	56.2	62.5
% of males in the gene pool	33.7	39.4	45	50.6	56.2
Maximum reproductive age	7.5	8.7	10	11.2	12.5
Mean litter size	1.3	1.5	1.7	1.9	2.1
Mortality of class 0-1	18.7	21.9	25	28.1	31.2
Mortality of adult males	9.75	11.38	13.00	14.63	16.25
Mortality of adult females	9.00	10.50	12.00	13.50	15.00

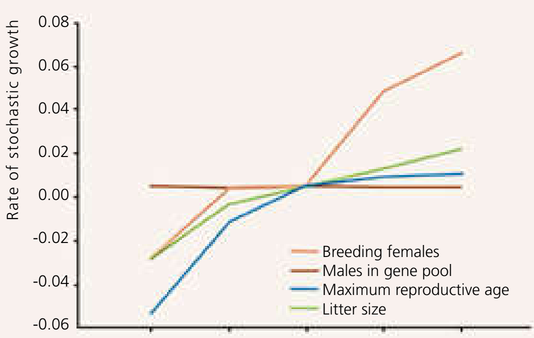


Figure 3. Sensitivity analysis for the reproductive parameters of the jaguar generic model

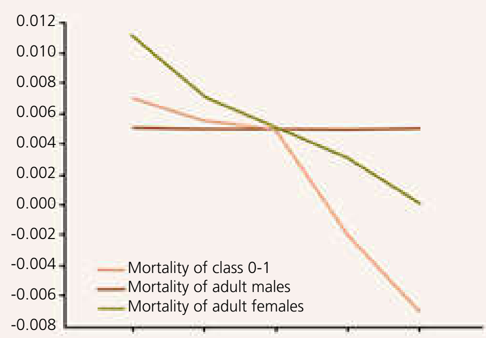


Figure 4. Sensitivity analysis for the mortality parameters of the jaguar generic model.

Risk analysis II: Sex and number of individuals hunted

Annual mortality caused by hunting can significantly reduce the annual growth rate of populations and increase the risk of extinction, especially in small populations.

To understand the various consequences of the hunting of adult jaguars, depending on the number of individuals hunted and their sex, we conducted a risk analysis modeling annual harvest of individuals in Table 7 from year 0 to 100.

As shown in Table 7 and Figure 5, the hunting of female jaguars leads to a decrease in the growth rate of the population (rstoc) and an increase in the probability of extinction. According to the generic model, populations in which more than 3% of adult females are hunted every year are not viable over 100 years.

Regional models

We decided to build a specific population model for each of the six regions of Mexico where the jaguar occurs: Maya Forest, Zoque Forest, Jalisco-Nayarit, Sonora, Tamaulipas, and Ría Lagartos. Population density and the different effects of catastrophes are the main differences between populations of these regions.

We ran several possible scenarios in each regional model to see the effect of the different anthropogenic pressures in each area. We modeled a scenario free of anthropogenic actions, one exploring the effect of hunting, and one to study the ef-

Table 7. Input parameters and results of the risk analysis of sex and amount of individuals hunted

Individuals hunted/year		Results	
% Males	% Females	R stoc	PE
10.00	0.00	-0.168	1.000
5.00	0.00	-0.060	0.918
2.50	0.00	0.004	0.000
0.00	10.00	-0.219	1.000
0.00	5.00	-0.082	0.994
0.00	2.50	-0.025	0.048
5.00	5.00	-0.086	1.000
2.50	2.50	-0.023	0.040
1.25	1.25	-0.003	0.000
0.00	0.00	0.005	0.000

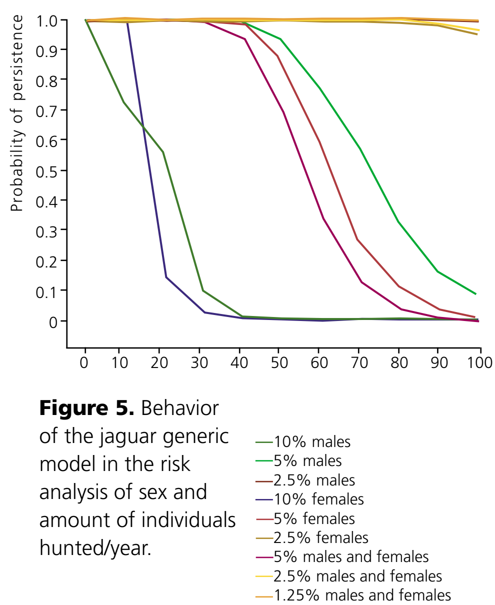


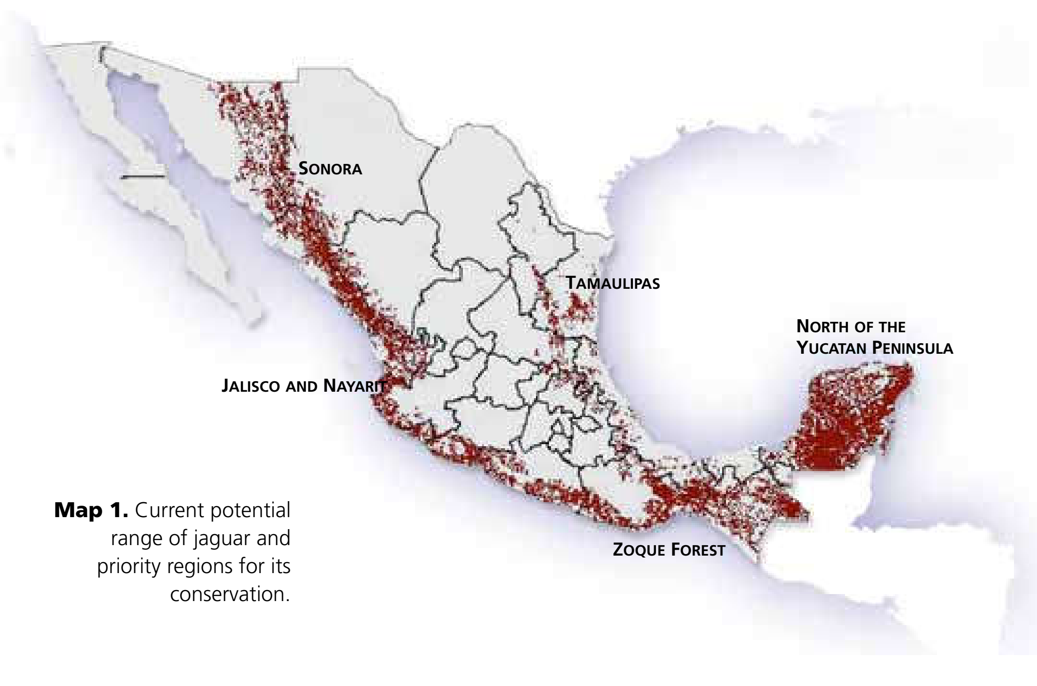
Figure 5. Behavior of the jaguar generic model in the risk analysis of sex and amount of individuals hunted/year.

fect of a reduction of K (carrying capacity) as a consequence of habitat loss and a decrease in prey availability. The reduction of K was a constant annual percentage, and the effect of hunting was the annual harvest of a percentage of individuals (50% males, 50% females) relative to population size. Map 1 shows the potential distribution of the jaguar in Mexico.

Tamaulipas

The estimates for this region are the following: a density of 3.5 individuals/100 km^2 and an area of 3,666 km^2 available (Ortega-Huerta and Medley, 1999; Caso, this volume; A. Rivera, pers. comm.); an annual deforestation rate of 0.27%, and an annual loss of 0.05% of carrying capacity due to overhunting of jaguar prey (Amin, 2004). Table 8 shows the input parameters of the model and the results of the modeling. Figure 6 shows population sizes in the different scenarios and the probability of persistence of the population over 100 years.

According to the model, the population in Tamaulipas would still be viable in 100 years without anthropogenic influences, although it would decrease from 128 to 80 individuals. If we consider the reduction of K, it would still be viable but would drop to less than 60 individuals. If we include hunting, the population would cease to be viable in 30 years and would be extinct in 100 years.



Map 1. Current potential range of jaguar and priority regions for its conservation.

Maya Forest

The estimates for the Maya Forest were the following: a density of 6.0 individuals/100 km², and an area of 62,593 km² available (Ceballos *et al.*, 2002; Ceballos *et al.*, 2005; Chávez, 2006; Chávez *et al.*, this volume; Zarza *et al.*, this volume); an annual deforestation rate of 0.7% (Conde, *et al.* 2010), and a reduction of 0.05% of K due to hunting (Escamilla *et al.*, 2000). According to available data, it is estimated that 3% of individuals are hunted every year (A. Rivera pers. obs.). Table 9 shows the input parameters of the model and the results of the modeling. Figure 7 shows population size in the different scenarios and the probability of persistence of the population over 100 years.

Over 100 years and without anthropogenic influences, the model does not show a decline in the Maya Forest population; however, a decrease in K would reduce the population to 500 individuals, and hunting would reduce it to 1,500 individuals. None of the scenarios considered shows a risk of extinction over 100 years (Figure 7).

Table 8. Input parameters and results of the different scenarios of the model for the population of Tamaulipas

	No	K	Hurricane*	Drought*	Change K	Hunting	r stoc	PE
No effects	128	147	6.7, 25, 5	30, 25, 0			-0.004	0.032
Loss of K	128	147	6.7, 25, 5	30, 25, 0	-0.32%		-0.007	0.040
Hunting	128	147	6.7, 25, 5	30, 25, 0		7.5% N	-0.069	1.000

* (frequency, % decrease of reproduction, % decrease of survival)

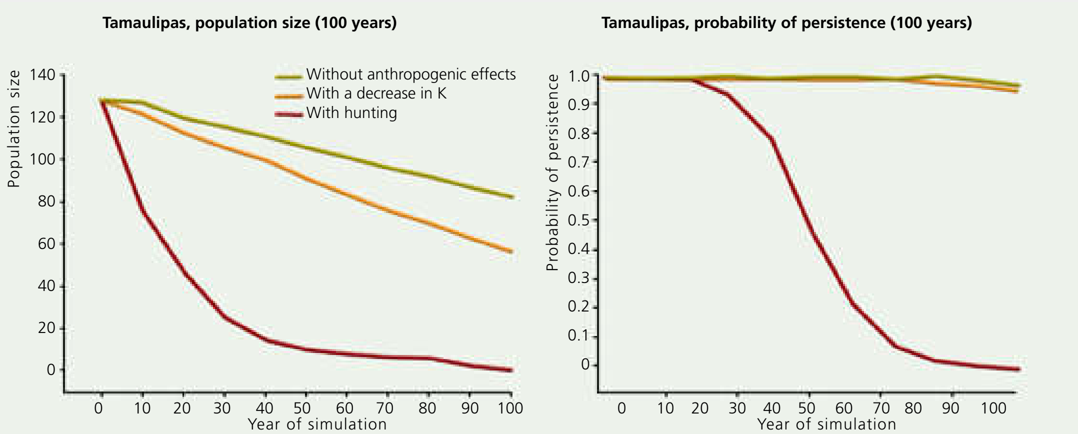


Figure 6. Population size and probability of persistence of the population of Tamaulipas, without anthropogenic effects, with a decrease in K, and with hunting.

Sonora

The estimates were the following: a density of 1.0 individuals/100 km^2, and an area of 15,000 km^2 available (Rosas, in press; C. López-González, pers. obs.). In this region, habitat loss and the hunting of jaguar prey is not estimated to have a significant impact on the decrease of K (O. Rosas and C. López-González pers. obs.). About 3.35% of jaguars are hunted every year, according to the estimates (O. Rosas and C. López-González pers. obs.). Table 10 shows the input parameters of the model and the results of the modeling. Figure 8 shows population size in the different scenarios and the probability of persistence of the population over 100 years.

Over 100 years and without anthropogenic influences, the model shows that the population in Sonora would decline to less than 50% of its original size; if the effect of hunting is considered, the population would barely reach the number of 20 individuals. The population would not be viable in any of the two scenarios (Figure 8).

Table 9. Input parameters and results of the different scenarios of the model for the population of Maya Forest

	No	K	Hurricane*	Drought*	Change K	Hunting	r stoc	PE
No effects	2000	2300	10, 25, 5	10, 25, 0			0.006	0.000
Loss of K	2000	2300	10, 25, 5	10, 25, 0	-0.75%		-0.005	0.000
Hunting	2000	2300	10, 25, 5	10, 25, 0		3% N	-0.003	0.000

* (frequency, % decrease of reproduction, % decrease of survival)

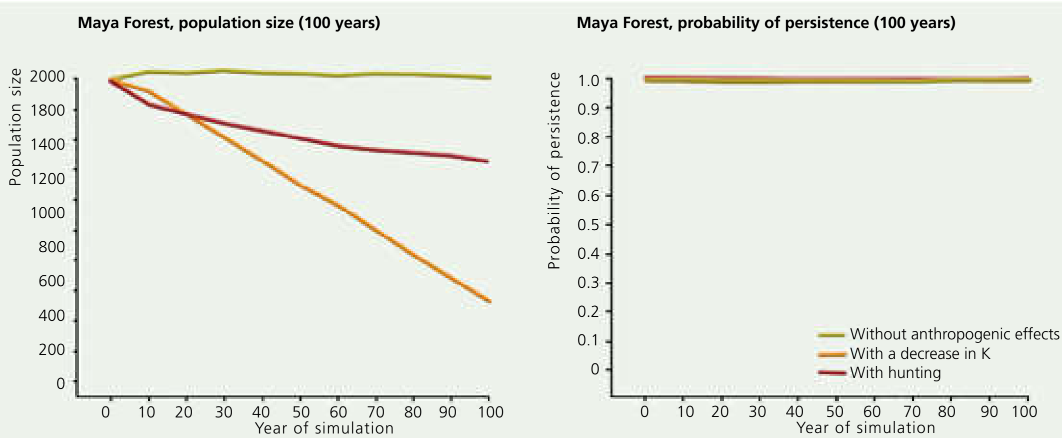


Figure 7. Population size and probability of persistence of the population of Maya Forest, without anthropogenic effects, with a decrease in K, and with hunting.

Jalisco-Nayarit

Density recorded in this region is 3.5 individuals/100 km^2, and an area of 4,000 km^2 is available (Núñez *et al*., 2002; 2006). The annual deforestation rate of the tropical deciduous forest is 2%, and the rate is believed to be even higher in the semi-evergreen forest. The effect of the reduction of natural prey due to overhunting is offset by predation on livestock. It is estimated that about 10% of the population is hunted every year. Table 11 shows the input parameters of the model and the results of the modeling. Figure 9 shows population size in the different scenarios and the probability of persistence of the population over 100 years.

Over 100 years, and without anthropogenic influences, the model shows that the population of Jalisco/Nayarit would still be viable, although it would drop from 140 to 110 individuals. A decrease in K would lead the population to extinction in 40 years, and hunting would lead it to extinction in 80 years.

Table 10. Input parameters and results of the different scenarios of the model for the population of Sonora

	No	K	Drought*	Hunting	r stoc	PE
No effects	150	172	20, 25, 10		-0.013	0.112
Hunting	150	172	20, 25, 10	3.3% N	-0.039	0.684

* (frequency, % decrease of reproduction, % decrease of survival)

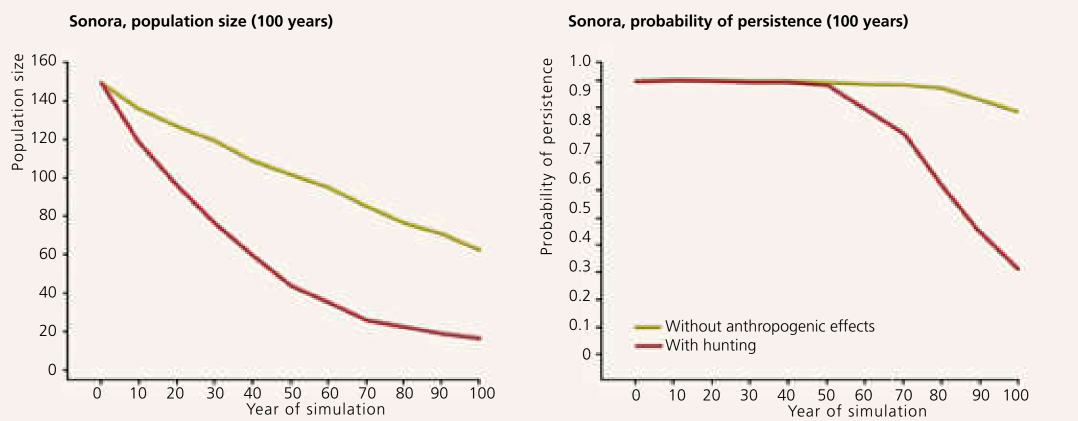


Figure 8. Population size and probability of persistence of the population of Sonora, without anthropogenic effects, with a decrease in K, and with hunting.

Northeastern Yucatan Peninsula

Density recorded is 3.0 individuals/100 km². An area of 700 km² is currently protected, and an additional 200 km² will soon be protected as well, which represents 25% of the area available (Faller *et al.*, 2002, this volume). Figure 12 shows the location of the north of the Yucatan Peninsula. According to the data available, it is estimated that 10% of individuals are hunted every year. The decline in the abundance of prey in the region does not seem concerning. The 2% annual deforestation rate is expected to remain the same for 10 years and then slow down because of the protected area status. Table 12 shows the input parameters of the model and the results of the modeling. Figure 11 shows population size in the different scenarios and the probability of persistence of the population over 100 years.

Over 100 years, and without anthropogenic influences, the model shows a drop in the Ría Lagartos population from 105 to 70 individuals; however, the population would still be viable. Considering the decrease in K, the population would drop to 50 individuals but would no longer be viable in 90 years. Considering the effect of hunting, the population would no longer be viable in 20 years and would become extinct in 70 years (Figure 11).

Table 11. Input parameters and results of the different scenarios of the model for the population of Jalisco/Nayarit

	No	K	Hurricane*	Drought*	Change K	Hunting	r stoc	PE
No effects	140	160	10, 25, 5	5, 25, 0			0.002	0.006
Loss of K	140	160	10, 25, 5	5, 25, 0	- 2.8%		-0.071	1.000
Hunting	140	160	10, 25, 5	5, 25, 0		10% N	-0.097	1.000

* (frequency, % decrease of reproduction, % decrease of survival)

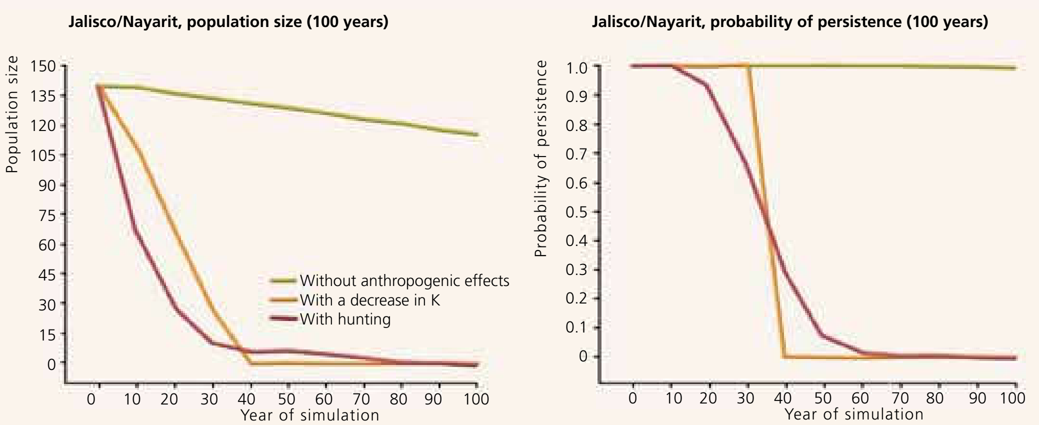


Figure 9. Population size and probability of persistence of the population of Jalisco/Nayarit, without anthropogenic effects, with a decrease in K, and with hunting.

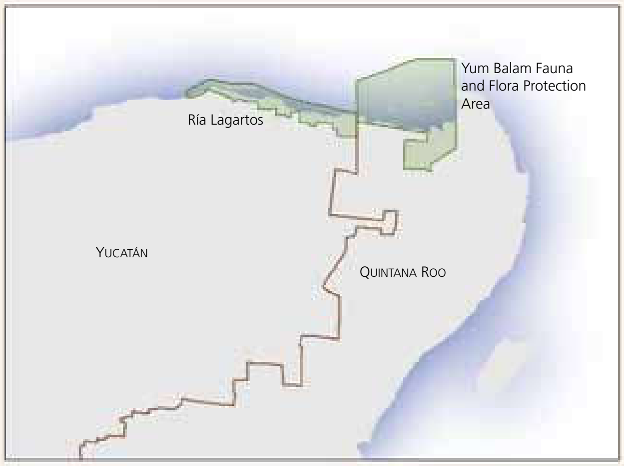


Figure 10. Northeastern of the Yucatan Peninsula

Table 12. Input parameters and results of the different scenarios of the model for the population of Ría Lagartos							
	No	**K**	**Hurricane***	**Change K**	**Hunting**	**r stoc**	**PE**
No effects	105	120	20, 25, 5			-0.003	0.048
Loss of K	105	120	20, 25, 5	- 2% durante 10 años	-0.008	0.118	
Hunting	105	120	20, 25, 5		10% N	-0.096	1.000

* (frequency, % decrease of reproduction, % decrease of survival)

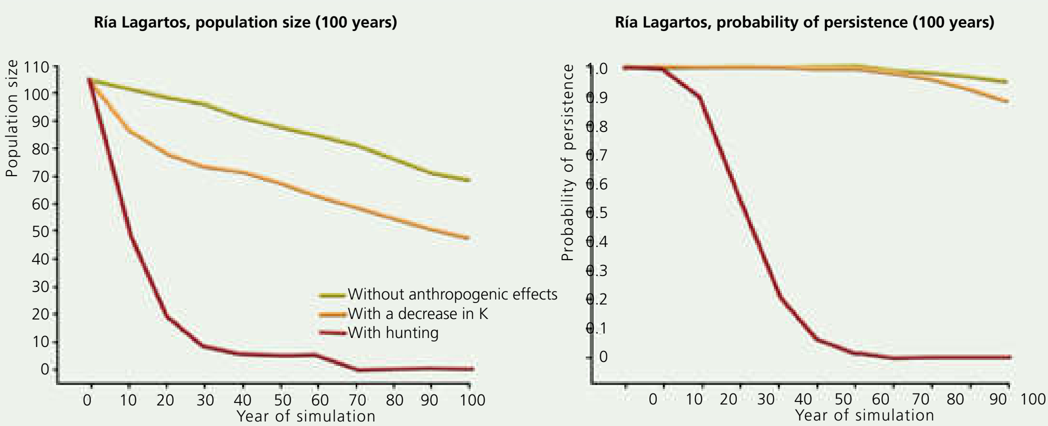


Figure 11. Population size and probability of persistence of the population of Ria Lagartos, without anthropogenic effects, with a decrease in K, and with hunting.

Zoque Forest

In the Zoque Forest, density reported is 4.0 individuals/100 km^2, and an area of 5,653 km^2 is available (4,600 km^2 in Los Chimalapas, plus 1,053 km^2 in La Sepultura and El Ocote, Lira *et al.*, this volume). According to the estimates, the annual deforestation rate is 0.12%, and 1% of individuals are hunted every year (I. Lira pers. obs.). Table 13 shows the input parameters of the model and the results of the modeling. Figure 12 shows population size in the different scenarios and the probability of persistence of the population over 100 years.

Over 100 years, and without anthropogenic influences, the model shows that the population in the Zoque Forest would drop from 220 to 210 individuals; considering the decrease in K or hunting would cause a somewhat greater drop in the population, but it would still be viable in 100 years.

Table 13. Input parameters and results of the different scenarios of the model for the population of Zoque Forest

	No	K	Hurricane*	Change K	Hunting	r stoc	PE
No effects	226	260	10, 25, 5			0.005	0.000
Loss of K	226	260	10, 25, 5	- 0.125%		0.002	0.000
Hunting	226	260	10, 25, 5		1% N	0.004	0.000

* (frequency, % decrease of reproduction, % decrease of survival)

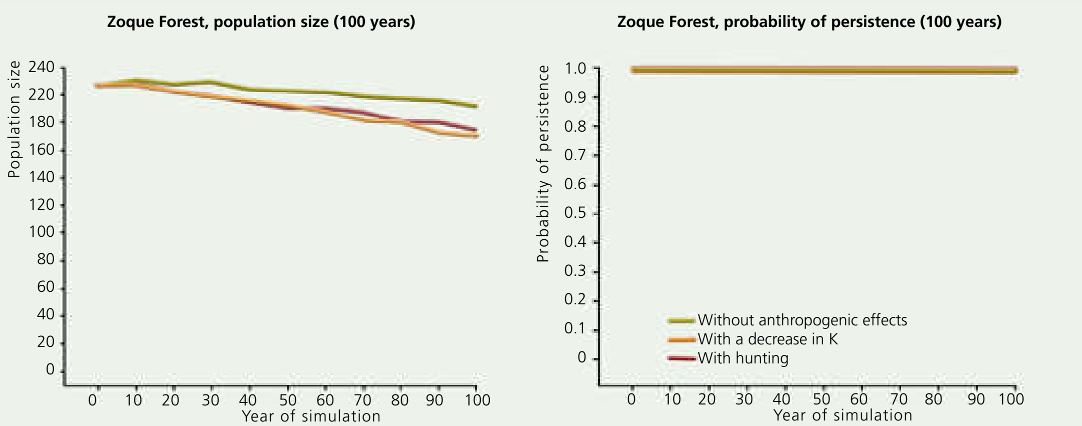


Figure 12. Population size and probability of persistence of the population of Zoque Forest, without anthropogenic effects, with a decrease in K, and with hunting.

Table 14. Regional targets and actions

Target	Actions	Person/ institution in charge	Period
Design regional jaguar conservation strategies for each of the priority areas. The strategies must consider the following: 1) the accuracy of the surface of existing federal, state and municipal protected areas. 2) Determine connectivity areas between existing protected areas or priority areas. 3) Identify breeding areas (source populations). 4) Designate new protected areas. Acknowledge communal, forest and private reserves as protected areas so that they can receive payments for ecosystem services. 5) Promote connectivity between populations and breeding areas, and declare federal, state and municipal protected areas. Coordination between Semarnat and Sagarpa. Continue identifying additional priority areas for jaguar conservation and its habitat. Long term.	Develop terms of reference for the identification and study of critical areas for jaguar conservation. Identify critical areas for the persistence and recovery of jaguar in Mexico, particularly source populations and connectivity between populations. Start the procedure to designate new protected areas (previous studies, regulatory impact assessments, etc.).	Jaguar Subcommittee.	6 months. 4 years. 8 years.
Economic alternatives compatible with conservation in important areas for the jaguar. Medium term.	Identify and stimulate the development of alternative productive activities with a lesser impact on the jaguar and its habitat.	Alfonso Aquino and Fernando Guadarrama.	
Well implemented environmental land planning programs in all jaguar priority areas. Long term. Promote the consideration of priority areas for jaguar in municipal development plans.	Identify municipalities in priority areas for jaguar conservation that do not have land planning programs and inform them about environmental land planning and its advantages.		2 years.

Regional strategies

The jaguar has a broad distribution in Mexico, from the south east to the center of the country, where its range splits to occupy the pacific and the northern coast, in Sonora. In the various plenary discussions, the group identified and selected a set of targets and actions. They were not only intended to be part of a general strategy for jaguar conservation in Mexico, but also part of a series of regional strategies. These strategies can be implemented in all the regions of Mexico where the jaguar occurs, but are flexible enough to adapt to the situation of each of these regions, their characteristics, cultures, resources, and so on. These regional target and goals are shown in Table 14.

Conclusions

The conclusions and recommendations derived from the various working groups in the workshop were the following:

1. Establish regional synergies for jaguar conservation.
2. Develop a national survey in the different regions with priority habitat for the species.
3. Request and promote agreements between various federal public bodies such as Semarnat, CFE (Mexico's Utility Company), Pemex (Mexico's state-owned oil monopoly), Sectur (Ministry of Tourism) and SCT (Ministry of Communications and Transport) to mitigate the impact generated by their projects.
4. Create the Mexican Jaguar Conservation Fund.
5. Build a link with civil society by raising awareness about the plight of the jaguar in Mexico.

Acknowledgments

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Glossary

CFE: *Comisión Federal de Electricidad* – Federal Utility Company
Conacyt: *Consejo Nacional de Ciencia y Tecnología* – National Council for Science and Technology
Conafor: *Comisión Nacional Forestal* – National Forestry Commission
Conanp: *Comisión Nacional de Areas Naturales Protegidas* – National Commission for Natural Protected Areas
DOF: *Diario Oficial de la Federación* – Mexican Federal Registry
Ejido: Common land granted to peasants in agrarian reforms
Hojanay: *Hombre Jaguar Nayarit*, A.C.
NOM: *Norma Oficial Mexicana* – Mexican Endangered Species List
PAPIR: *Programa de Apoyo a los Proyectos de Inversión Rural* – Program of Support to Rural Investment Projects
PE: Probability of extinction
Pemex: *Petróleos Mexicanos*, Mexico's state-owned oil monopoly
PGR: *Procuraduría General de la República* – General Attorney of the Republic
PHVA: Population and Habitat Viability Assessment
PND: *Plan Nacional de Desarrollo* – National Development Plan

PPY: *Pronatura Península de Yucatán*, A.C.
PREP JAGUAR: *Programa de Recuperación de Especies Prioritarias-Jaguar* – Recovery Project for Priority Species-Jaguar
Procampo: *Programa de Apoyos Directos al Campo* – Program for Direct Support to Agriculture
Profepa: *Procuraduria Federal de Protección al Ambiente*, the law enforcement arm for wildlife protection in Mexico
Progan: *Programa de Productividad Ganadera* – Livestock Productivity Improvement Program
Sagarpa: *Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación*- Ministry of Agriculture, Rural Development, Fisheries and Food
SCT: *Secretaría de Comunicación y Transporte* – Ministry of Communications and Transport
SE: *Secretaría de Economía* – Ministry of Finance
Sectur: *Secretaría de Turismo* – Ministry of Tourism
Sedena: *Secretaría de la Defensa Nacional* – Ministry of Defense
Sedesol: *Secretaría de Desarrollo Social* – Ministry of Social Development
Semarnat: *Secretaría de Medio Ambiente y Recursos Naturales* – Ministry of Agriculture and Natural Resources
SHCP: *Secretaría de Hacienda y Crédito Público* – Ministry of Treasury and Public Credit
Sierra: Mountain range
UNAM: *Universidad Nacional Autónoma de México* – National Autonomous University of Mexico

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