POPULATION AND HABITAT VIABILITY ASSESSMENT OF JAGUARS IN MEXICO

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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 pop-

ulation 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.

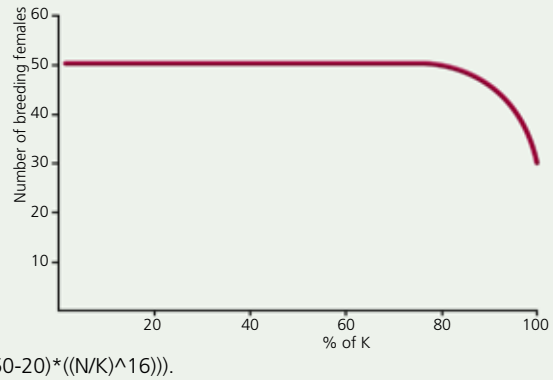

Figure 1. Equation used in the basic model to estimate density dependence in the % of breeding females.

% 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

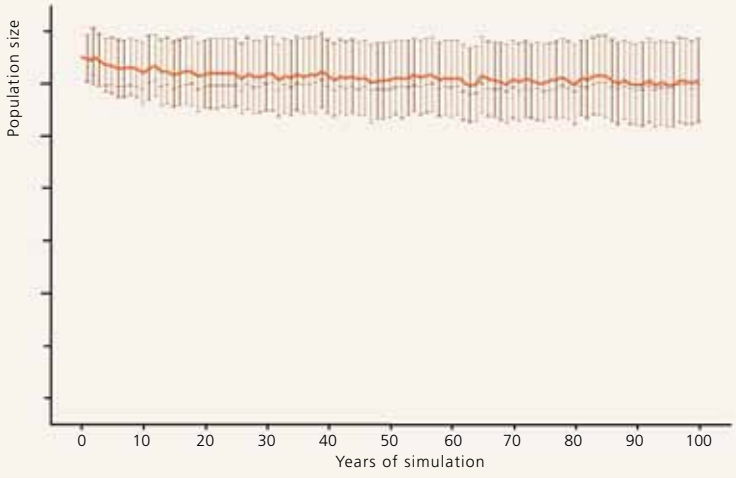

Figure 2. 100-year projection of population size (N ± DS), assuming that the population is free of anthropogenic impacts

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

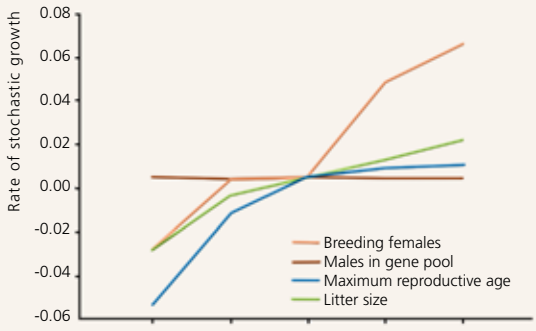

Figure 3. Sensitivity analysis for the reproductive parameters of the jaguar generic model

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

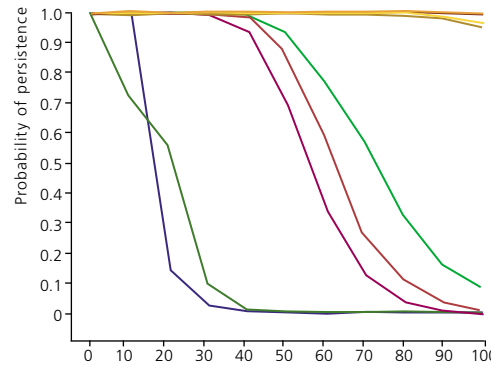

Figure 5. Behavior of the jaguar generic model in the risk analysis of sex and amount of individuals hunted/year.

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 km^2, and an area of 62,593 km^2 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)

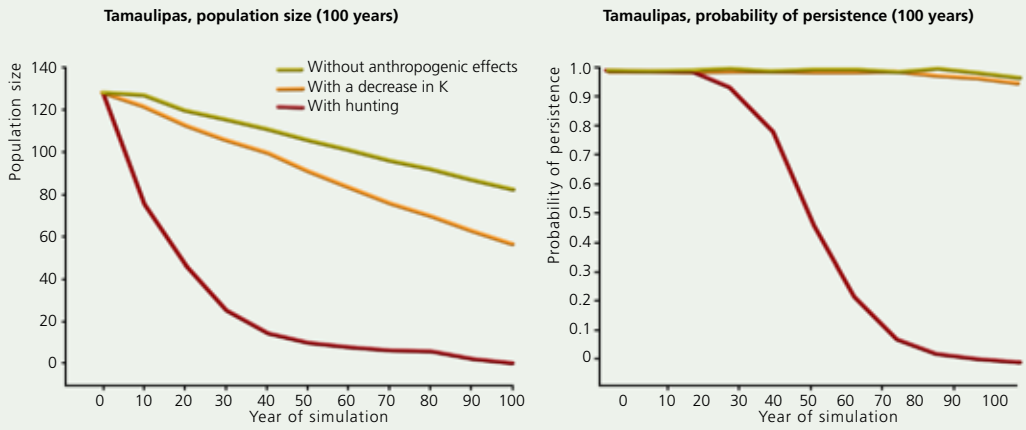

Figure 6. Population size and probability of persistence of the population of Tamaulipas, without anthropogenic effects, with a decrease in K, and with hunting.

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)

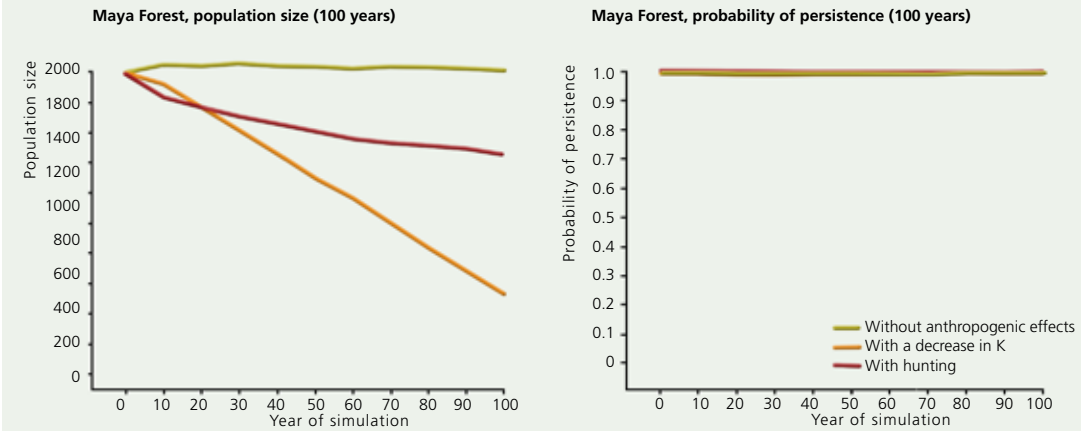

Figure 7. Population size and probability of persistence of the population of Maya Forest, without anthropogenic effects, with a decrease in K, and with hunting.

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)

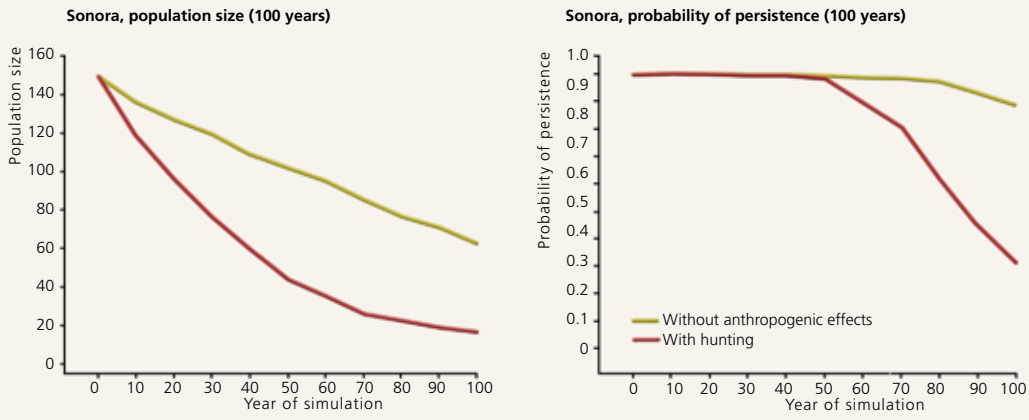

Figure 8. Population size and probability of persistence of the population of Sonora, without anthropogenic effects, with a decrease in K, and with hunting.

Northeastern Yucatan Peninsula

Density recorded is 3.0 individuals/100 km^2. An area of 700 km^2 is currently protected, and an additional 200 km^2 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)

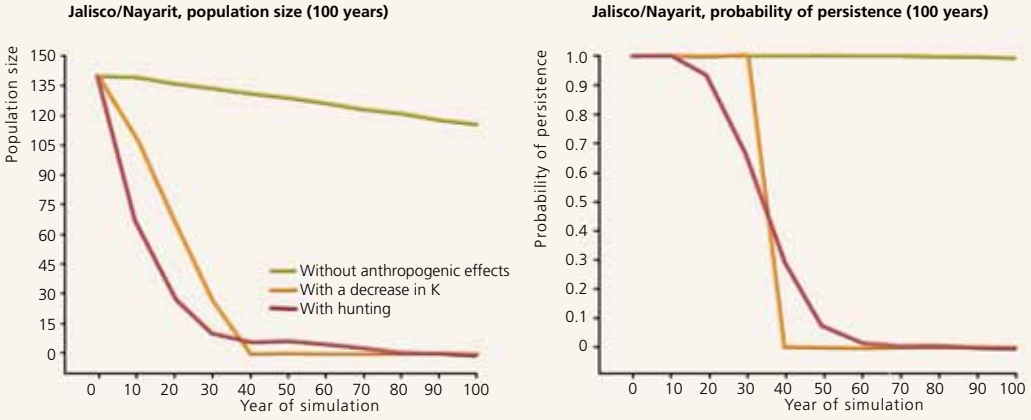

Figure 9. Population size and probability of persistence of the population of Jalisco/Nayarit, without anthropogenic effects, with a decrease in K, and with hunting.

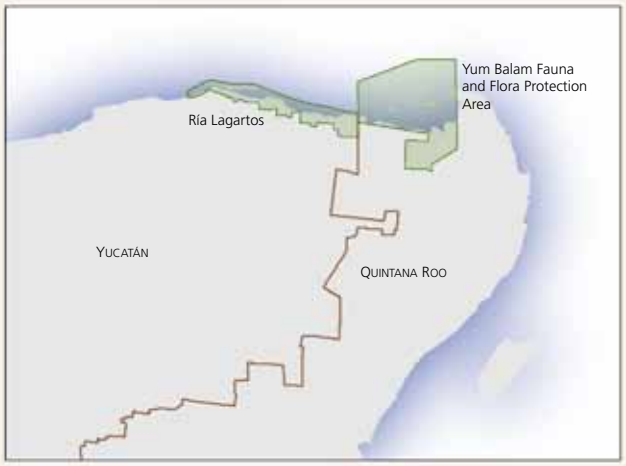

Figure 10.
Northeastern of the
Yucatan Peninsula

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	-0.008	0.118	
				10 años			
Hunting	105	120	20, 25, 5		10% N	-0.096	1.000

* (frequency, % decrease of reproduction, % decrease of survival)

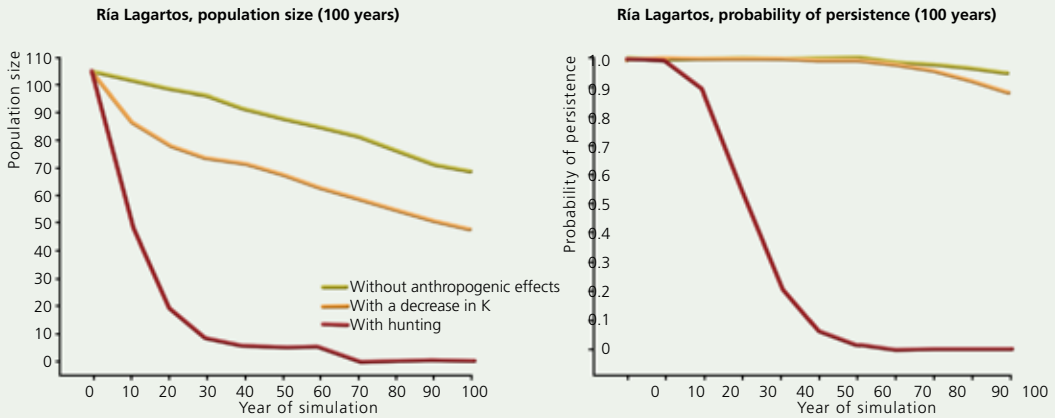

Figure 11. Population size and probability of persistence of the population of Ria Lagartos, without anthropogenic effects, with a decrease in K, and with hunting.

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)

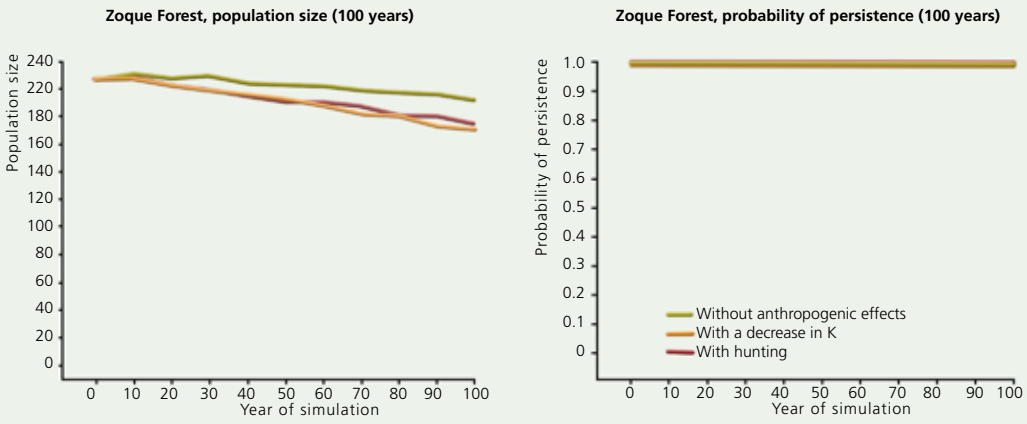

Figure 12. Population size and probability of persistence of the population of Zoque Forest, without anthropogenic effects, with a decrease in K, and with hunting.

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