

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

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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 la 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 km², pero en algunos machos alcanzó hasta 1,000 km². La densidad varió de 3.3 a 6.6 individuos por 100 km². 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 km², some males ranged up to 1,000 km². Density ranged from 3.3 to 6.6 individuals per 100 km². 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 Commission 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 (CamTrakker™) 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

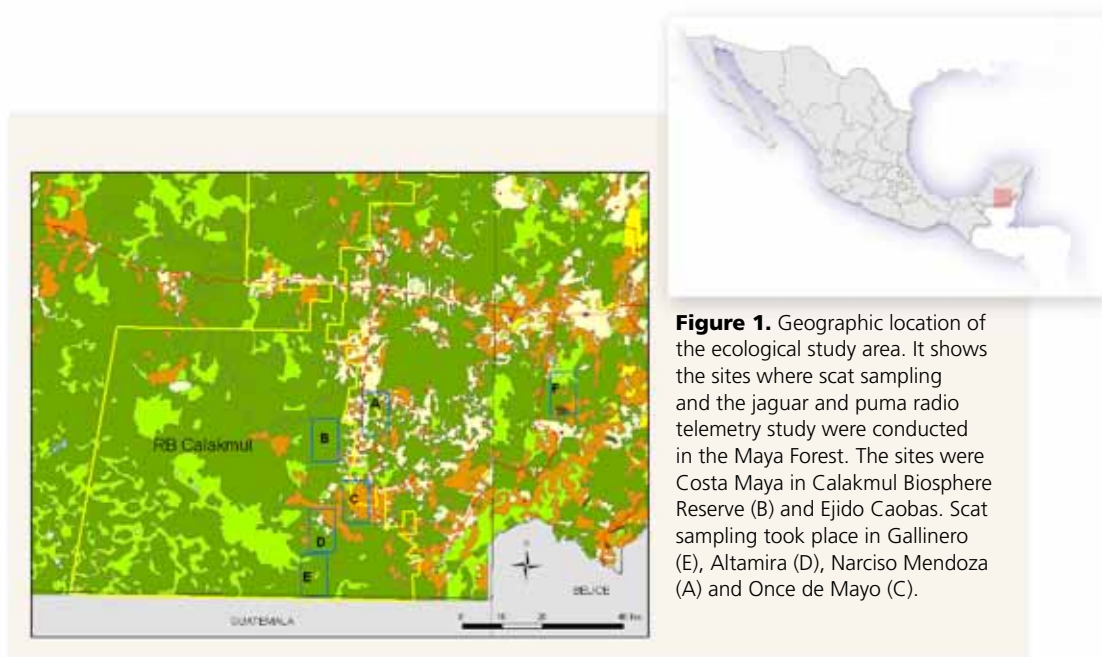


Figure 1. Geographic location of the ecological study area. It shows the sites where scat sampling and the jaguar and puma radio telemetry study were conducted in the Maya Forest. The sites were Costa Maya in Calakmul Biosphere Reserve (B) and Ejido Caobas. Scat sampling took place in Gallinero (E),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

paths at 2 km intervals, covering an area of 48 km². 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 km² cells on a area of 49 km². 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 km² rectangle divided into 60, 1 km² 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 km² for jaguars and 133 km² for pumas. Satellite radio collars showed a home range of more than 1,000 km² 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 km² 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

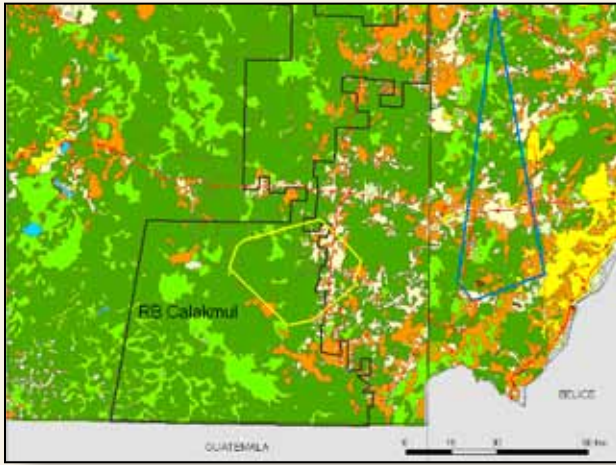


Figure 2. Home ranges of two males, one in Calakmul Biosphere Reserve (Tony, in yellow) and one in Ejido Caobas (Lico, in blue).

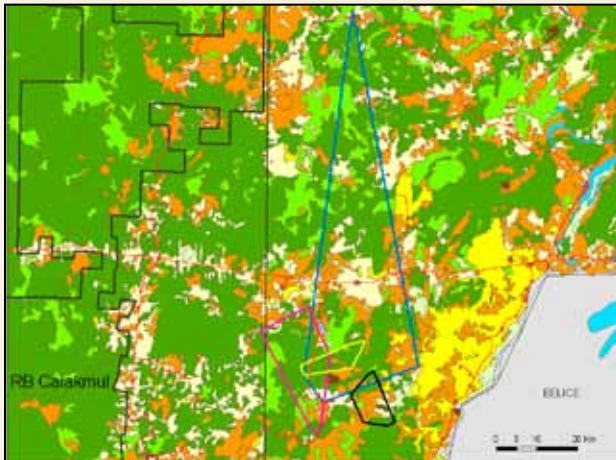


Figure 3. Home ranges of Lico, a male (blue) and three females (Melissa, Dalia and Verónica) in Ejido Caobas.

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 km² was estimated in the study area. The initial findings of one individual/15-30 km² 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 Cockscomb Basin in Belize, where density is one individual/13-16 km² (Rabinowitz and Nottingham, 1986), and Mexico, such as Chamela-Cuixmala Biosphere Reserve on the Pacific coast, where density was estimated at 1 jaguar/33 km² (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).

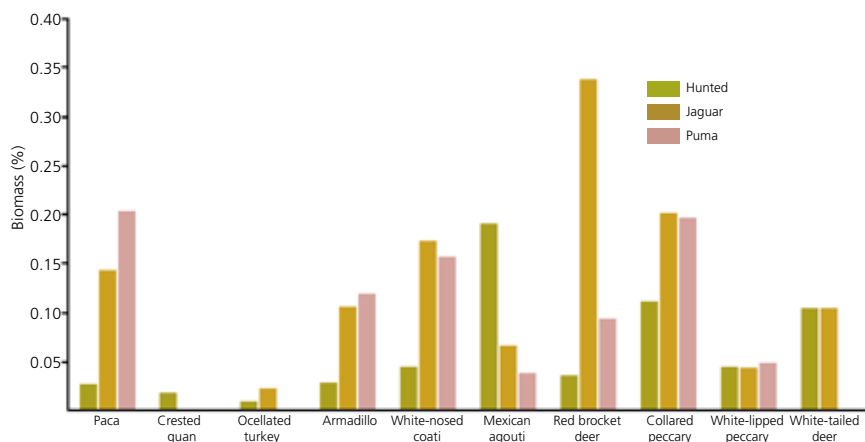


Figure 5. Biomass of the ten most important bird and mammal species for hunters in Ejido Cristóbal Colón, southern Yucatan Peninsula (Escamilla *et al.*, 2000). Data for jaguars and pumas were obtained by analyzing 45 and 15 scats, respectively.

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 km² 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.

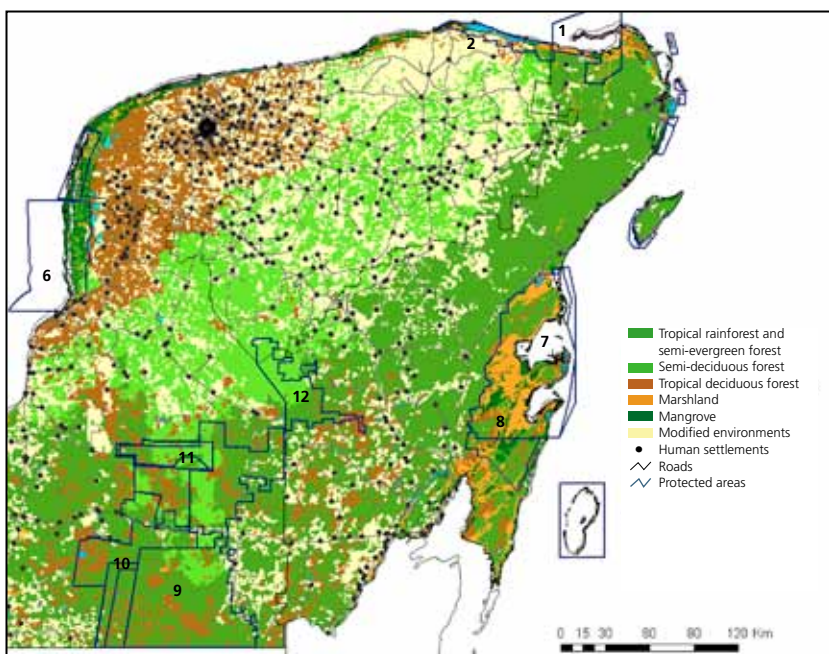
Name of protected area	Area (km ²)	Potential habitat (km ²)	Population size*	
			6.67	3.33
Yum Balam (1)	1540	84	5.6	2.8
Ría Lagartos (2)	604	139	9.3	4.6
Punta Nizuc (3)	26	-	-	-
A. de Puerto Morelos (4)	3340	-	-	-
Ría Celestún (5)	597	2	0.1	-
Los Petenes (6)	2832	3	0.2	0.1
Sian Ka'an (7)	5280	1687	112.5	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 km².

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.



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