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# Use of remote cameras to evaluate ocelot (*Leopardus pardalis*) population parameters in seasonal tropical dry forests of central-western Mexico

DOI 10.1515/mammalia-2016-0114

Received August 4, 2016; accepted March 8, 2017; previously published online April 12, 2017

**Abstract:** The ocelot is one of the most studied felid species in the neotropics yet most of our current knowledge comes from tropical rain forests and protected areas. Therefore, we lack a comprehensive understanding on how the species abundance varies in terms of ecological parameters across its full distribution range. This is particularly true for the species population in the Northern Hemisphere, as data of ocelot populations occurring in tropical dry forests are scarce. In this study, we focused on: a) generating population data (density and sex ratios), based on camera-trapping, for ocelot occurring in the vast and understudied tropical dry forest of the western Pacific of Mexico. b) Comparing the variation in species abundance and density across its distribution range, including a larger set of studies from the Northern Hemisphere, contrasting parameters between rain forests and tropical seasonal ecosystems and re-examining the assumed relationship between precipitation and ocelot abundance. Overall, we identified 17 ocelots in our study sites and estimated an average density of 23.7 individuals (ind) per 100 km<sup>2</sup> with a female to male ratio >1. No significant differences in ocelot density was found between seasonal tropical forests and rain forests studies (Wilcoxon test,  $W = 71$ ,  $p = 0.7675$ ). Moreover, we found no support for the relation

between ocelot density and precipitation (only when restricting our analysis to rain forest data the fit of the regression model was close to be significant,  $R^2 = 0.2463$ ,  $p = 0.07107$ ). Our results indicate that tropical seasonal ecosystems and dry forest in particular, may present ocelot population with similar levels of abundance than tropical rain forests. We observed that precipitation is a poor predictor of ocelot abundance. In our study, we observed that overall local ecological factors (e.g. prey abundance and interspecific interactions) influenced the spatial and temporal abundance of ocelots.

**Keywords:** camera-trap; density; precipitation; unprotected tropical dry forest.

## Introduction

The ocelot (*Leopardus pardalis* Linnaeus 1758) is the most abundant and widely distributed felid in the neotropics (Caso et al. 2008). Its distribution range goes from the Mexico-Texas border to northern Argentina across a variety of habitat types (Emmons and Feer 1997, Murray and Gardner 1997). The species broad distribution has encouraged its use as a model species to look at the effects of environmental factors (e.g. precipitation) and human impacts on population parameters such as abundance (Di Bitetti et al. 2008).

Over the last decade the number of camera-trapping studies focusing on evaluating ocelot population abundance has increased (Trolle and Kéry 2003, Maffei et al. 2005, Di Bitetti et al. 2006, Boas et al. 2009). Therefore, more data is currently available to evaluate how ocelot population abundance, density, sex ratios and activity patterns vary in the different regions, and ecological scenarios. Unfortunately, still the majority of study areas have been located in tropical rain forests areas within or near protected areas (e.g. Noss et al. 2012, Palomo-Muñoz et al. 2014, Salvador and Espinoza 2016). Previous comprehensive analysis, performed mostly in tropical rain forests sites, revealed that ocelot densities

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vary enormously, from 5.4 to 56.4 individuals (ind) per 100 km<sup>2</sup> (Trolle and Kéry 2003, Diaz-Pulido and Payán-Garrido 2011). However, less information exists on how ocelot population parameters vary in seasonal ecosystems, such as tropical dry forests. This is true for the northern hemisphere, where tropical dry forests constitute a key biome for biodiversity conservation. Unfortunately, in Mexico these biomes are experiencing a higher forest loss rate than rain forests (Ceballos and Valenzuela 2010).

Earlier research results hypothesized the potential existence of a positive relationship between ocelot densities and large scale environmental factors as precipitation, which were assumed as the factors influencing the variation in felid population abundance due to biome productivity (Di Bitetti et al. 2008, Gomes da Rocha et al. 2016).

Currently the information documenting how ocelot populations respond to the strong seasonality of the tropical dry forests of the Northern Hemisphere is scarce. How these abundances compare with the populations from tropical rain forests in southern latitudes is still unclear, increasing the need to obtain more information from northern seasonal dry forests. In addition, global climate change is a threat that may alter rainfall regimes, influencing biome distribution as lower precipitation is expected for large areas of Mexico (Rehfeldt et al. 2012), with a potential effect on ocelot abundances for the different kinds of forests.

Besides, understanding each biome suitability in terms of felid abundances may be crucial for the design of effective conservation strategies and population viability analysis (Vale et al. 2015). The increase in number of ocelot studies by camera-trapping over a wider range of climatic regimes, including the Northern Hemisphere, offers the opportunity to examine again the relationship between ocelot density and precipitation reducing regional or forest type biases. There is a premise that Mexico supports the northernmost viable populations of ocelot (Haines et al. 2006, Zerinskas and Pollio 2013) however, the species is classified as endangered in the national red list: NOM-059-SEMARNAT-2010 (SEMARNAT 2010). The main threats faced by the species are illegal hunting, and habitat loss and fragmentation (Ceballos and Valenzuela 2010). The tropical dry forest of the Pacific coast offers the largest continuous extent of habitat available (ca. 14% of the country) among the different biomes in Mexico (Ceballos and Valenzuela 2010). But the region is threatened by a high deforestation rate (Mas-Causel 2005), with a low number of large protected areas and there is a total absence of studies on ocelot populations abundances.

Our main objective was to obtain ocelot population data (i.e. density, abundance and sex ratios) through a camera-trapping design conducted in two areas in

a region where tropical dry forest is the predominant vegetation type, in the central-western Pacific coast of Mexico. Second, we compiled a data set consisting of camera-trapping studies to compare ocelot population estimates between seasonal dry forest ecosystems and rain forests. Finally, we examined the data from all the camera-trapping studies, containing a more balanced number of study cases in terms of forest types, regions and hemispheres, and evaluated if a positive relationship between precipitation and ocelot density existed and that ocelot abundances were higher near the Ecuador (latitudinal theory) under the hypotheses established by Di Bitetti et al. (2008). However, in our analysis we only included results from comparable studies, those methodologically standardized (only camera-traps). Our premises were that the ocelots in tropical seasonal ecosystems would present similar abundance and variation than those documented in tropical rainforests, as the results from the published studies exhibited considerable variation.

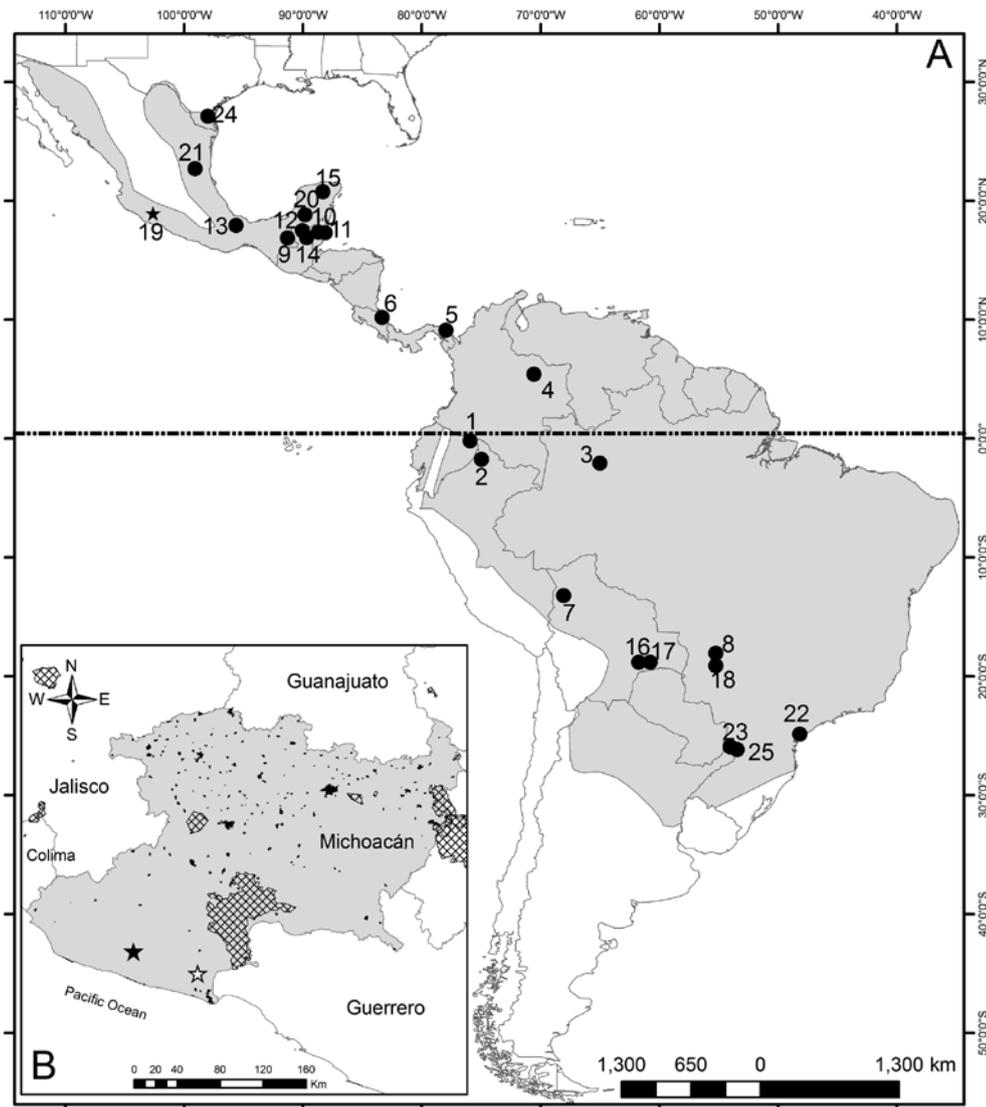
## Materials and methods

### Study site

This study was conducted in two sites located within the central-western Pacific coast of Mexico, in the state of Michoacan: El Naranjal (18°19'55"N, 102°47'32"W) and Playa del Venado (18°10'8"N, 102°18'29"W) which were 54 km apart. Selection of these sites was based on their degree of isolation from human settlements and safety to conduct field work due to existence of illegal activities in the region (Figure 1). In both sites the predominant vegetation was tropical dry forest and to a lesser extent tropical semi-deciduous forest; oak forest was restricted to higher mountain elevations (Charre-Medellín 2012). The average annual temperature in our study sites is 24°C and annual rainfall ranges between 1000 and 1310 mm (Charre-Medellín 2012).

### Sampling design

Three surveying sessions were conducted: March–June, 2010 (dry season); November 2010–February 2011 (late rainy season) and March–June, 2011 (dry season). We installed 18 camera-traps (Wildview® Xtreme) in the field to document ocelot presence (nine camera-traps per site, Grand Prairie, TX, USA). The mean distance between nine camera-trap stations per site was 1840 m (minimum 500 m



**Figure 1:** Potential distribution of ocelot and location of study site a in western Mexico.

(A) Location of study sites (star) within the potential ocelot distribution (gray area) and of studies using camera-traps and capture-recapture models included in our review (see, Table 2). (B) Location of the two sampling sites in the central-western of Mexico (black star = El Naranjal and white star = Playa del Venado). Urban areas are shown in black and protected natural areas are indicated with a black grid.

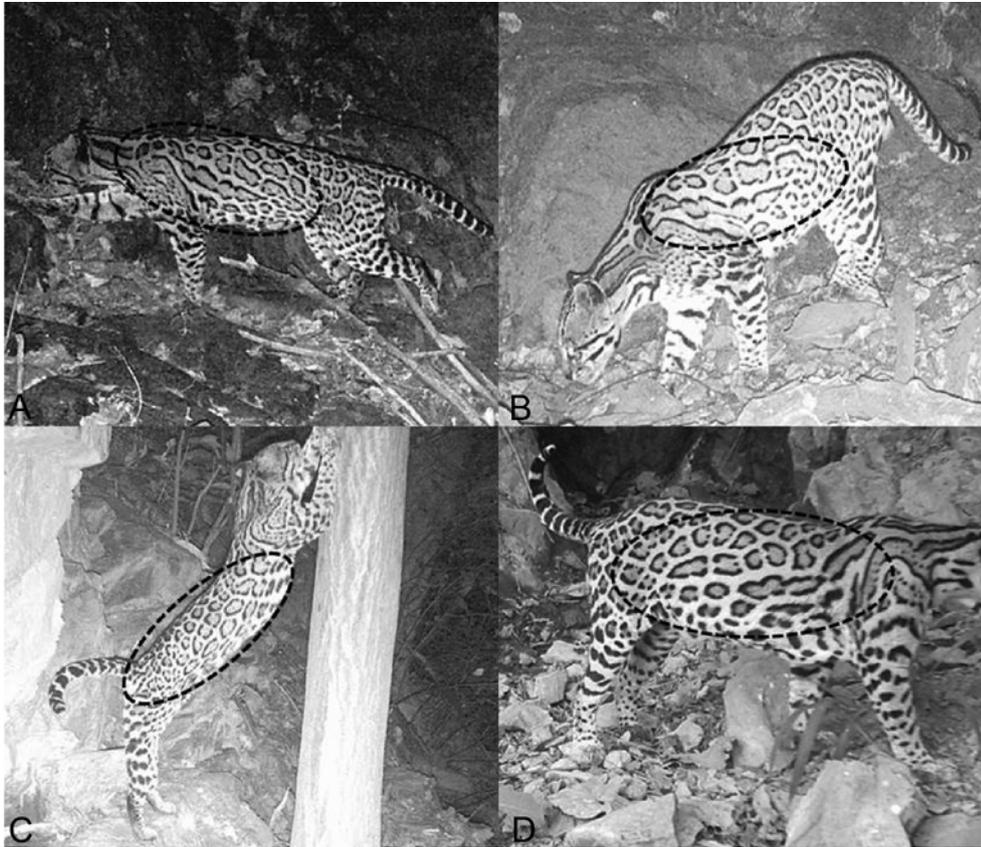
and maximum 4018 m). We programmed the camera-traps to take three photographs per capture event and to be active again after 1 min. The cameras were checked every 30 days to verify optimal functioning, replace batteries if needed and to download information from the memory cards. At each site, five camera-traps were set on wildlife trails and four on small filtration springs, which constitute the only local source of water (Haines et al. 2006).

### Estimation of ocelot abundance and density

In each surveying season and site, we calculated a relative abundance index (RAI), which was defined as the

proportion of capture events divided by the sampling effort (camera-trap days) and standardized by 100 camera-trap days (O'Brien et al. 2003, Rovero and Marshall 2009). We assumed that all photographs of ocelots recorded by the same camera-trap within the same 1-h interval and site corresponded to the same individual unless differences were clearly evident (Botello et al. 2008, Monroy-Vilchis et al. 2011). Individual ocelots were identified based on a combination of distinctive traits such as rosettes, spots, stripes, scars, size and sex (Moreno and Bustamante 2009, Palomo-Muñoz et al. 2014) (Figure 2).

The abundance of ocelots was estimated using the capture-recapture method and the CAPTURE software (Rexstad and Burnham 1991). We made two assumptions



**Figure 2:** Examples of markings employed for individual recognition of ocelots.

(A) and (B) Photographic recapture of same individual in the locality of El Naranjal. (C) and (D) Different individuals recorded in the locality of Playa del Venado. The oval indicates an example of a set of unique spot and stripes patterns employed for individual identification.

to estimate capture probability ( $p$ ): (1) the population was demographically and geographically closed during the sampling period and (2) each individual within the sampling area had a  $p > 0$  of being recorded (Noss et al. 2012, Avila-Nájera et al. 2015).

For each locality and surveying period, we generated a capture history matrix: 0 = no capture, and 1 = presence; using a sampling period of 6 days (Di Bitetti et al. 2006, Kolowski and Alonso 2010, Diaz-Pulido and Payán-Garrido 2011). These matrices were uploaded to the program CAPTURE to generate abundance estimations assuming capture probabilities were different among individuals but constant during the season (model Mh) (Karanth and Nichols 1998, Avila-Nájera et al. 2015). We calculated ocelot density by dividing the corresponding abundance estimate by the effective area sampled (EAS) which is outlined using a circular buffer created around each camera-trap station. The distance used to create these buffers was the mean maximum distance moved (MMDM) by ocelots in each locality (Silver 2004). We considered 12 km<sup>2</sup> as the minimum EAS for each season-site

combination. Such area size was considered reliable for density estimates according to a study where the effective survey area in tropical dry forest was analyzed by comparing camera-trap and telemetry results (Maffei and Noss 2008). It has been shown that use of MMDM and “traditional” capture-recapture methods generate similar abundance estimations to those obtained by spatially-explicit capture-recapture methods (Tobler and Powell 2013, Gomes da Rocha et al. 2016). Density estimations were standardized as the number of ocelots/100 km<sup>2</sup> to compare our results with all ocelot studies conducted with camera-trapping in other regions and habitats.

### Compilation of ocelot camera-trapping studies and statistical analysis

An extensive revision of scientific literature was performed, considering all the published studies in scientific journals, as well as graduate thesis or dissertations.

From each study we obtained the following data: study area, country in which the study was conducted, vegetation type, mean annual rainfall, area status (protected or unprotected), survey effort, survey design, number of localities surveyed, number of camera stations, distance among camera stations, model applied to conduct capture-recapture analysis, number of ocelots identified, sex ratio and estimated densities.

We used program R (Development Core Team 2016) for statistical analysis. To test for differences in ocelot densities between tropical rain forests and tropical seasonal ecosystems, we employed a non-parametric two-sample test (Wilcoxon test). We also tested the relationship between precipitation and ocelot density across the neotropics based on 25 camera-trap studies and applying single linear regression models. The explanatory and response variables were log transformed. We conducted these analyses using the whole data set first and afterwards tropical rain forests and seasonal forests ecosystem data independently. All these statistical comparisons were based on a significance level  $\alpha = 0.05$ .

## Results

We recorded a total of 186 capture events after completing a total sampling effort of 4648 camera-trap days. We recorded 113 capture events at El Naranjal and 73 at Playa del Venado (Table 1). The greatest RAI value in El Naranjal occurred during the 2011 dry season (5.7 ocelots/100 trap days), whereas the highest RAI in Playa del Venado occurred during the 2010 dry season (4.4 ocelots/100 trap days) (Table 1).

We were able to identify 11 ocelots at El Naranjal (three males and eight females) and six in Playa del Venado (two males and four females) (Table 1). The highest bias in the sex ratio was observed during the late rainy season of 2010 and the dry season of 2011 at El Naranjal (1:7, male to female ratio) (Table 1).

## Ocelot abundance and density estimations

The MMDM by the ocelots according to the camera-trap records varied among the sampling seasons and sites. The longest distance was 4.9 km in “El Naranjal” during the 2010 dry season. This distance translated in an estimated EAS equal to 163.7 km<sup>2</sup>. At “Playa del Venado”, the longest MMDM was 1.68 km in the 2011 dry season,

**Table 1:** Estimated ocelot population parameters in two sites of the western coast of Mexico during two sampling periods.

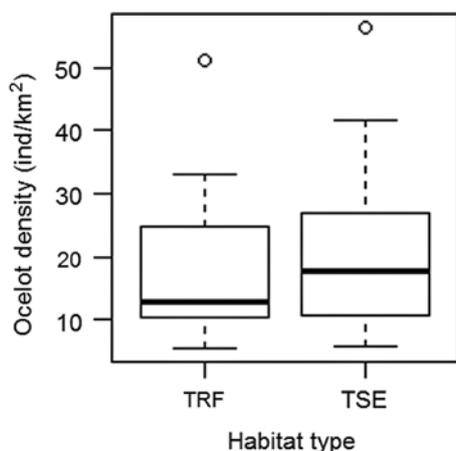
|   | El Naranjal |            |            | Playa del Venado |             |             |                            |
|---|-------------|------------|------------|------------------|-------------|-------------|----------------------------|
|   | Dry 2010    | Humid 2010 | Dry 2011   | Dry 2010         | Humid 2010  | Dry 2011    | Total/average <sup>a</sup> |
| Capture effort (trap day)                   | 801         | 785        | 792        | 750              | 725         | 795         | 2270                       |
| Independent capture events                  | 31          | 37         | 45         | 35               | 13          | 25          | 73                         |
| Capture rate (individuals per 100 trap day) | 3.9         | 4.6        | 5.7        | 4.4              | 1.6         | 3.1         | 3.0                        |
| Individuals recognized (male:female)        | 3:4         | 1:7        | 1:7        | 1:3              | 1:4         | 2:2         | 2:4                        |
| Capture/recapture ratio                     | 27/20       | 30/21      | 33/24      | 15/10            | 14/9        | 12/8        | 41/27                      |
| Estimated abundance ± SD                    | 8 ± 1.4     | 10 ± 2.0   | 9 ± 1.4    | 4 ± 0.84         | 6 ± 2.1     | 6 ± 2.4     | 5.3 ± 1.7 <sup>a</sup>     |
| Capture probability                         | 0.21        | 0.15       | 0.18       | 0.18             | 0.12        | 0.12        | 0.14 ± 0.03 <sup>a</sup>   |
| MMDM (km)/EAS (km <sup>2</sup> )            | 4.9/163.7   | 2.06/49.3  | 3.84/111.3 | 1.17/12.3        | 1.19/12.6   | 1.68/20.4   | 1.34/15.1 <sup>a</sup>     |
| Density (ind/100 km <sup>2</sup> )          | 4.8 ± 1.7   | 20.2 ± 8.1 | 8.0 ± 2.5  | 32.5 ± 21.7      | 47.6 ± 33.3 | 29.4 ± 23.5 | 36.5 ± 22.5 <sup>a</sup>   |

Densities are number of individuals (ind) per 100 km<sup>2</sup>. <sup>a</sup>average.

which produced an EAS estimate of 20.4 km<sup>2</sup> (Table 1). The average distance traveled by ocelot females in “Playa del Venado” and “El Naranjal” was  $1.3 \pm 0.6$  and  $2.6 \pm 1.2$  km, respectively. In comparison, males moved on average  $1.6 \pm 0.8$  and  $3.6 \pm 1.6$  km, respectively. The overall ocelot density in the study was 23.7 ind/100 km<sup>2</sup> considering all the periods and both localities. Although higher abundance and density were estimated for the localities during the rainy season, their differences are not significant as observed in the broad overlap of their standard deviations (Table 1). The highest estimated density occurred during the 2010 rainy season: 20.2 ind/100 km<sup>2</sup> (El Naranjal) and 47.6 ind/100 km<sup>2</sup> (Playa del Venado) (Table 1).

### Comparison of ocelot density between habitat types and rainfall

No differences were observed when comparing ocelot density estimates between tropical seasonal ecosystems (including dry forests) and rain forests (median values = 17.7 vs. 12.75, respectively; Wilcoxon test,  $W = 71$ ,  $p = 0.7675$ , Figure 3), and we did not find a relationship between ocelot density and precipitation using all the estimates of ocelot density pooled together ( $R^2 = 0.0288$ ,  $p = 0.416$ ). Likewise, we did not find evidence of a relationship between density and rainfall when only seasonal ecosystems were examined ( $R^2 = 0.02414$ ,  $p = 0.6483$ , Figure 4). The nearest we were to find a significant relationship between rainfall and ocelot density was when we

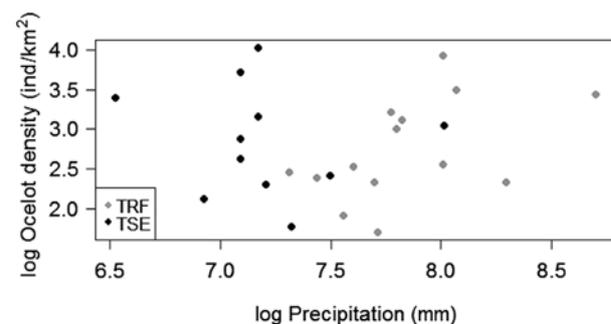


**Figure 3:** Estimated ocelot density in tropical rainforest sites (TRF) and tropical seasonal ecosystems (TSE). Thick horizontal lines correspond to median values. The upper and lower extremes of the boxes correspond to the first and third quartiles, whiskers correspond to 1.5 times the interquartile range of the data and empty circles are outliers.

considered only rain forest sites ( $R^2 = 0.2463$ ,  $p = 0.07107$ , Figure 4). No major effect was observed of excluding the non-protected sites ( $n = 2$ ) from the regressions.

## Discussion

Despite that our study area is characterized by a low annual rainfall (1300 mm) and a severe drought season lasting up to 8 months, the density (23.7 ind/100 km<sup>2</sup>) and number of individual ocelots identified ( $n = 17$ ) are among the highest for Mexico even when compared to tropical rain forest localities having higher rainfall and a greater level of protection. Examples of these areas are: the Lacandon rain forests, in the state of Chiapas, which has an annual average rainfall equal to 3000 mm but an ocelot abundance estimated to be 12.9 ind/100 km<sup>2</sup> (De la Torre et al. 2016), and the tropical forests of Yucatan with a rainfall of 1511 mm and an ocelot abundance estimated to be 5.9 ind/100 km<sup>2</sup> (Avila-Nájera et al. 2015). Moreover, it stands out that the highest density estimated in this study, was only slightly inferior (17%) to the highest ocelot density (39 ind/100 km<sup>2</sup>) documented, the tropical dry forest of the Chamela-Cuixmala Reserve in Mexico, obtained by a telemetry assessment (Fernández 2001). Therefore, our results support the idea that tropical dry forests of the western Pacific constitute a suitable habitat for ocelots in Mexico. Further evidence to categorize our study site as “suitable” habitat for ocelots come from: (a) our observations, documenting the presence of females with 3-month old kittens at both localities during the wet season, which coincides with the reproductive season reported for the species in Mexico (Leopold 1959, Aranda 2005), (b) a high number of individual ocelots identified



**Figure 4:** Relationship between estimated ocelot density and precipitation in tropical rain forests (TRF) and tropical seasonal ecosystems (TSE).

Ocelot density in tropical rain forest was the closest to show a significant increase with annual precipitation ( $R^2 = 0.2463$ ,  $p = 0.071$ ).

and (c) frequent recording of the presence of ocelot prey species such as Cracids (*Ortalis poliocephala*), Columbids (*Leptotila verreauxi*), black iguanas (*Ctenosaura pectinata*) and squirrels (*Notocitellus annulatus*, Merriam, 1903) (Charre-Medellín 2012). Moreover, the higher female to male ratio suggest a high breeding potential. In our studied localities, a higher ratio of females was observed, especially during the humid season. A higher female to male ratio is not uncommon for the species, as 65% of the camera-trap studies present a number of females ranging from 1.1 to three per male (Table 2). A bias caused by the methodology is unlikely because 35% of the studies present higher number of males, and in some studies the ratio is as high as 10 males per female (Table 2). Potential explanations for this result may be related with the behavior of the males. Home ranges are larger in males than in females, as well as the maximum daily distances traveled (Dillon and Kelly 2008). Our hypothesis is that in our study sites the home ranges of the males are smaller during the dry season. Water availability in the landscape may limit their movements. In contrast, during the humid season the males may disperse or increase their home ranges, as water is available in more places. Female home ranges are smaller, and probably that is the reason why the number of males observed is smaller.

In addition to rainfall, variation in ocelot density has been related to a diverse number of factors operating at the local scale, such as: extent of mature forest, prey availability, competitor presence and abundance and level of habitat protection (i.e. protected vs. not protected) (Noss et al. 2012, Martínez-Hernández et al. 2014). We posit that in our study, three factors are particularly important to influence ocelot abundance and its seasonal variation: availability of water springs, competitor presence and reduced human activity.

Frequent use of water springs by ocelots aided in individual recognition and the combined use of cameras on trails and springs allowed to verify that ocelots were moving back and forth. We assume that springs may be a local key resource influencing the movements and permanence of local ocelot's populations. This may also determine the individual territory size and location (Silver et al. 2004, Dillon and Kelly 2007, 2008, Noss et al. 2012, Palomo-Muñoz et al. 2014). Local water availability during the dry season may be a significant factor behind the wide variation in ocelot abundance across seasonal tropical forests (Wallace et al. 2000, Morgart et al. 2005, Henschel 2008, Sánchez-Lalinde and Pérez-Torres 2008).

Several authors have highlighted the importance of seasonal variation in water availability as a factor affecting

the distribution and abundance of vertebrate populations in tropical dry forests (Wolff 2001, Gannon et al. 2007, Charre-Medellín et al. 2010, Charre-Medellín 2012). In this study, we evidenced variation in ocelot abundance, and in the female to male ratio in relation with the seasonal variation in precipitation. We recorded a higher ocelot density after the rainy season, in comparison with the dry season. It is likely that ocelot territory size differs as a function to changes in local resource availability driven by seasonality.

Regarding the role of predator presence as another key variable affecting ocelot abundance, we noticed that the lowest ocelot density in “El Naranjal” correlated with a greater cougar (*Puma concolor*) activity (4.4 records/100 trap days). Whereas at Playa del Venado we observed a cougar capture rate considerably lower (0.7 records/100 trap days) (Table 1), (Charre-Medellín 2012). Future studies should evaluate how competitor presence relates to seasonal variation, and prey abundance that may also affect ocelot density. Our premise is that the results from our study were not affected by human impacts, as evidence of hunting was not found. Villages larger than 500 inhabitants were located 15 km away from Playa del Venado and 30 km away from El Naranjal (Figure 1) (Charre-Medellín 2012). However, there is still the need to evaluate how ocelot abundance vary in the landscape under different densities of human activity in the region.

From a large scale perspective, rainfall and latitude have been considered as parameters that influence ocelot densities across the neotropics. The general hypothesis is that higher ocelot densities occur near the Ecuador where rainfall is higher (Di Bitetti et al. 2008, Martínez-Hernández et al. 2014). However, our results failed to support the role of rainfall as a main driver of variation in ocelot abundance. Only when the analysis was focused on tropical rainforest sites, a positive relationship between rainfall and ocelot abundance was close to be detected (Figure 4). In contrast, there were several cases in which areas of tropical dry forests or seasonal tropical forests had a higher ocelot density than the average ocelot abundance estimated across rain forest sites (18.7 ind/100 km<sup>2</sup>) and semi-deciduous tropical forests (19.4 ind/100 km<sup>2</sup>). In fact, a tropical dry forest site in eastern Bolivia had the third highest ocelot density recorded in the continent: 41.5 ocelots/100 km<sup>2</sup> (Maffei et al. 2005). As previously mentioned, we hypothesized that factors operating locally (e.g. prey biomass and top predator abundance) might be overriding the influence of local or regional climate. Ocelot prey, competitors and predators vary across neotropical forests and may play a more important role, such as high *Puma*

Table 2: Characteristics of ocelot studies using camera-traps and capture-recapture models.

| Country      | Vegetation type (precipitation mm) | Conservation status | No. camera stations | Model to estimate density | Trapping effort (camera-trap/ days) | No. of individuals identified | Sex ratio Male:female | Density (individuals/ 100 km <sup>2</sup> ) | Source                                 |
|--------------|------------------------------------|---------------------|---------------------|---------------------------|-------------------------------------|-------------------------------|-----------------------|---|--|
| 1 Ecuador    | RF (3200)                          | Protected           | 26                  | MMDM                      | 2340                                | 35–36                         | 11:19–17:14           | 33.0 <sup>a</sup>                           | Salvador and Espinoza 2016             |
| 2 Peru       | RF (3000)                          | Protected           | 23                  | MMDM                      | 983–2085                            | 22–27                         | 11:10–12:13           | 51 <sup>a</sup>                             | Kolowski and Alonso 2010               |
| 3 Brasil     | RF (2373)                          | Protected           | 50                  | SECR                      | 7020                                | 19                            | 10:8                  | 24.8 <sup>a</sup>                           | Gomes da Rocha et al. 2016             |
| 4 Colombia   | RF (2236)                          | Protected           | 21                  | MMDM                      | 1283                                | 6                             | 1:3                   | 5.47  | Diaz-Pulido and Payán-Garrido 2011     |
| 5 Panama     | RF (6000)                          | Protected           | 14                  | ½ MMDM                    | 490                                 | 11                            | 6:5                   | 31.3 <sup>b</sup>                           | Moreno and Bustamante 2009             |
| 6 Costa Rica | RF (4000)                          | Protected           | 10                  | MMDM                      | 600                                 | 5                             | –                     | 10.3  | González-Maya and Cardenal-Porras 2011 |
| 7 Bolivia    | RF (2440)                          | Protected           | 69                  | ½ MMDM                    | 1018                                | 17                            | 4:3                   | 20.2 <sup>ab</sup>                          | Ayala et al. 2010                      |
| 8 Brasil     | STF (1800)                         | Protected           | 52                  | MMDM                      | 504                                 | 9                             | 2:6                   | 11.2  | Trolle and Kelly 2005                  |
| 9 Mexico     | RF (3000)                          | Protected           | 29                  | SECR                      | 1920                                | 14                            | 4:10                  | 12.9  | De la Torre et al. 2016                |
| 10 Belize    | RF (1500)                          | Protected           | 7–19                | ½ MMDM                    | 239–1577                            | 4–19                          | 2:2–9:10              | 11.7 <sup>ab</sup>                          | Dillon and Kelly 2007                  |
| 11 Belize    | RF (2000)                          | Protected           | 7–17                | MMDM                      | 238–1513                            | 9                             | 5:4                   | 12.6  | Dillon and Kelly 2008                  |
| 12 Guatemala | STF (1350)                         | Protected           | 33                  | ½ MMDM                    | 1455                                | 38                            | –                     | 10.0 <sup>b</sup>                           | Moreira et al. 2007                    |
| 13 Mexico    | RF (2500)                          | Unprotected         | 29                  | MMDM                      | 8529                                | 9                             | 5:3                   | 22.6  | Pérez-Irinea and Santos-Moreno 2014    |
| 14 Guatemala | RF (1700)                          | Protected           | 25                  | SECR                      | 1150                                | 17                            | 6:11                  | 10.83                                       | Palomo-Muñoz et al. 2014               |
| 15 Mexico    | STF (1200)                         | Protected           | 27                  | MMDM                      | 2160                                | 12                            | 6:6                   | 13.9  | Torres-Romero 2009                     |
| 16 Bolivia   | TDF (1200)                         | Protected           | 16–31               | MMDM                      | 960–2280                            | 18–42                         | –                     | 41.5 <sup>a</sup>                           | Maffei et al. 2005                     |
| 17 Bolivia   | STF (1200)                         | Protected           | –                   | ½ MMDM                    | –                                   | 5–69                          | –                     | 17.7 <sup>ab</sup>                          | Noss et al. 2012                       |
| 18 Brasil    | STF (1300)                         | Protected           | 30                  | MMDM                      | 450                                 | 9                             | 4:5                   | 56.4  | Trolle and Kéry 2003                   |
| 19 Mexico    | TDF (1300)                         | Unprotected         | 9–9                 | MMDM                      | 2378–2270                           | 11–6                          | 3:8–2:4               | 23.7 <sup>a</sup>                           | This study                             |
| 20 Mexico    | STF (1511)                         | Protected           | 22–27               | MMDM                      | 1936–1755                           | 9–10                          | 6:3–6:4               | 5.9 <sup>a</sup>                            | Avila-Nájera et al. 2015               |
| 21 Mexico    | TDF (1017)                         | Protected           | 34–40               | SECR                      | 1240–2856                           | 15                            | 10:1                  | 8.3 <sup>a</sup>                            | Martínez-Hernández et al. 2014         |
| 22 Brasil    | STF (3014)                         | Protected           | 14–19               | MMDM                      | 585                                 | 6                             | 2:6                   | 21.0  | Fusco-Costa et al. 2010                |
| 23 Argentina | RF (2200)                          | Protected           | 34–39               | MMDM                      | 1409–1631                           | 17–34                         | 6:9–9:20              | 10.27 <sup>a</sup>                          | Di Bitetti et al. 2006                 |
| 24 USA       | TS (680)                           | Protected           | 18                  | ½ MMDM                    | 658                                 | 3                             | 1:2                   | 14.8 <sup>b</sup>                           | Haines et al. 2006                     |
| 25 Argentina | RF (1919)                          | Protected           | 42–47               | MMDM                      | 1871–2059                           | 10–33                         | –                     | 6.7 <sup>a</sup>                            | Di Bitetti et al. 2008                 |

RF, rainforest; TDF, tropical dry forest; STF, semi-deciduous tropical forest; TS, tropical scrub. <sup>a</sup>Mean of different density estimates reported in the same study. <sup>b</sup>Estimates correspond to an equivalent MMDM model.

*concolor* presence associate with lower ocelot density for one of our study sites.

It is important to notice that our database differ in several aspects from that used by Di Bitetti et al. (2008) to assess the influence of rainfall on ocelot abundance. The most noticeable difference was that we only analyzed camera-trap derived studies. Despite this restriction, we were able to have a sample size comparable to that used by Di Bitetti et al. (2008) including several recent studies; 15 of them were published after 2008. Moreover, our ocelot abundance dataset spanned over a wider range of rainfall (680–6000 mm) compared to Di Bitetti et al. (2008) (500–2600 mm). Therefore, our dataset constitutes a more realistic, and likely standardized, description of variation in ocelot abundance across neotropical forests.

## Conclusions

The tropical dry forests of western Mexico are more important for the long term conservation of ocelot populations than previously believed. In the absence of local population estimates for the few existing protected areas in the region, we recommend the inclusion of our areas as a part of carefully designed wildlife corridor network. Such corridor may strengthen the existing large reserves of western Mexico, such as Cuixmala-Chamela, Sierra de Manatlán, Zicuirán-Infiernillo and Nanchititla, by facilitating the movement of ocelot and large carnivores such as jaguar (*Panthera onca*) maintaining their gene flow, creating a interconnected network of protected areas (Charre-Medellín et al. 2015).

**Acknowledgments:** We appreciate the assistance from a wide range of people and institutions. We thank the Coordinación para la Investigación Científica at UMSNH for partially funding this research, and CONACYT for a graduate studies fellowship provided for JFCM (239248). We appreciate the field support given by students of Lab Vertebrate Priority Terrestrial and Faculty Biology for the facilities granted and UMSNH for the preparation of the manuscript.

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