OCELOT *Leopardus pardalis* (CARNIVORA: FELIDAE) SPATIAL ECOLOGY IN A FRAGMENTED LANDSCAPE OF COLOMBIA

Cristian Cruz-Rodríguez [1, 2], José F. González-Maya [2, 3*], Abelardo Rodríguez-Bolaños[1], Amancay A. Cepeda-Mercado[2] , Diego Zárrate-Charry[4] and Jerrold L. Belant [5]

[1]Universidad Distrital Francisco José de Caldas, Carrera 3 No. 26A – 40, Bogotá, Colombia.

[2]ProCaT Colombia. Carrera 13 No. 96-82 Oficina 205. Bogotá, Colombia.

[3*]Instituto de Ecología, Universidad Nacional Autónoma de México, Circuito Exterior s/n, Ciudad Universitaria Coyoacán, México D.F., México.

[4]Department of Forest Ecosystems and Society,Oregon State University, Corvallis,OR 97331, USA

[5]Carnivore Ecology Laboratory, Forest and Wildlife Research Center, Mississippi State University, Mississippi State, Mississippi, United States.

Autor de correspondencia: José F. González-Maya: jfgonzalezmaya@gmail.com

ABSTRACT

Ocelots *Leopardus pardalis* (Linnaeus, 1758) are one of the most common felids in the Neotropics and in the absence of large carnivores, can function as apex predators. Despite occupying numerous habitats across its range, including human-dominated landscapes, there is limited information on how ocelots use fragmented landscapes. We radio-tracked a female ocelot in a fragmented landscape of the Caribbean region of Colombia from November 2010 to January 2011 to estimate home range and habitat use. We obtained 100 locations overall; home range size was 9.64 km^2 using the 95% fixed kernel density estimate. Rivers and

roads were the main variables related with the locations and the ocelot selected for natural forests but also used disturbed habitats. Home range size and habitat use was similar to previous studies, but we observed greater use of disturbed habitats. As ocelots become the top predators in many fragmented landscapes of the Neotropics, it is important to understand how they use landscapes and could serve as surrogates for conservation.

Keywords: Home range, habitat use, Sucre, radio-telemetry, Colombia.

RESUMEN

El ocelote *Leopardus pardalis* (Linnaeus, 1758) es uno de los felinos más comunes en el Neotrópico y en ausencia de los grandes carnívoros, pueden funcionar como depredadores tope. A pesar de ocupar numerosos hábitats a través de su distribución, incluyendo paisajes dominados por el hombre, hay información limitada sobre cómo los ocelotes utilizan paisajes fragmentados. Realizamos radio-seguimiento de un ocelote hembra en un paisaje fragmentado de la región Caribe de Colombia entre noviembre de 2010 y enero de 2011 para estimar el ámbito hogareño y uso de hábitat. Se obtuvieron 100 ubicaciones en total; el ámbito de hogar fue de 9.64 km^2 utilizando la estimación de la densidad del núcleo fijo del 95%. Los ríos y las carreteras fueron las principales variables relacionadas con las ubicaciones así como el individuo prefirió los bosques naturales, pero también utilizó hábitats perturbados. El tamaño del ámbito hogareño y uso de hábitat fue similar a estudios previos, pero se observó un mayor uso de los hábitats perturbados. A medida que los ocelotes se convierten en los principales depredadores en muchos paisajes fragmentados del Neotrópico, es importante entender cómo usan los paisajes y podrían servir como especies sustitutas en conservación.

Palabras clave: ámbito de hogar, uso de hábitat, Sucre, radio-telemetría, Colombia.

INTRODUCTION

Leopardus pardalis (Linnaeus, 1758) is the largest spotted-cat of the *Leopardus* genus in America (Nowell and Jackson 1996) and one of the six species present in Colombia (Alberico *et al.*, 2000). It is considered the most common cat species in most lowland Neotropical areas, and is distributed from the United States to northeastern Argentina and Uruguay (Caso *et al.,* 2008). Despite its' wide distribution and potentially high abundance across its range, there is relatively little information regarding its ecology, population status, and response to anthropogenic activities (Gonzalez-Maya and Cardenal-Porras, 2011), especially in the Neotropical region. Ocelots are considered solitary (Haines *et al.,* 2006) and cryptic (Di Bitetti *et al.,* 2006), they are excellent climbers and are considered semi-arboreal, though they hunt on the ground investing large amounts of time walking (Emmons and Feer, 1999) and are active during day and night (Di Bitetti *et al.,* 2006, Maffei and Noss, 2008). The species occurs in diverse habitats, from tropical and subtropical humid and dry forests to scrublands (Di Bitetti *et al.,* 2008), and is generally associated with water bodies (Emmons, 1988). Ocelots typically select areas with dense vegetation (Di Bitetti *et al.,* 2006,Di Bitetti *et al.,* 2008) but also occur in fragmented areas (Michalski *et al.,* 2010); however, still how ocelots use fragmented habitats remains un-

clear (Michalski *et al.,* 2010). In Colombia ocelots are distributed across most of the country up to 4300 masl (Pinilla-Buitrago *et al.,* 2015), however, almost no information exists on its ecology and conservation, and even distribution is uncertain. The ocelot is considered as Least Concern globally by the IUCN Red List of Threatened Species (Caso *et al.,* 2008), however, specific populations of Colombia are considered Near Threatened (Jorgenson *et al.,* 2006). Furthermore, as the agricultural and livestock frontier advance, there is still little information on how ocelots respond to habitat disturbance and fragmentation. Here we present the first telemetry study for ocelots in Colombia to analyze its spatial ecology (i.e., home range and habitat use) in a fragmented landscape of the Caribbean region of Colombia.

MATERIALS AND METHODS

Study site

We conducted the study from November 2010 to January 2011 in the Colosó Primatological Research Station within the Serranía de Coraza and Montes de María Forest Protective Reserve (sc&MM FPR), in the department (i.e., province) of Sucre, Colombia (Figure 1). The study area is located in the biogeographic province of the Peri-Caribbean belt (Hernández Camacho *et al.,* 1992), has a mean annual temperature of 26.8 °C, relative humidity of 77 % and mean annual precipitation of 1,000–2,000 mm (Aguilera Díaz, 2005). The reserve includes 6,653 ha of tropical dry forest with elevations from 200 to 560 m asl containing the most important forest remnants in the department of Sucre (Cruz-Rodríguez *et al.,* 2011). The region has a long history of intensive land use and habitat fragmentation, with expanding small-scale agriculture, human settlements and livestock production (Pineda-Guerrero *et al.,* 2015); Sucre department currently retains only 12 % of the original forest cover (Cruz-Rodríguez *et al.,* 2011).

Methods

To evaluate the spatial ecology of ocelots in this fragmented landscape, we captured and followed a female ocelot through radio-telemetry. Though we try to capture more individuals, it was only possible to capture the tracked female. The individual was trapped on 15 October 2011 with the assistance of several farmers from the nearby community of Navas. The ocelot was chased with dogs and forced to climb a tree where it was captured and transported to the research facility. Afterwards the individual was chemically immobilized using a mixture of Zoletil (0.4 ml) and Atropin (0.02 ml) before being placed in a transportation cage. During immobilization we measured the ocelot and attached a radio collar (Model M1830; Advanced Telemetry Systems, Isanti, MN, USA). After full recovery, we released the ocelot in an area within the Reserve with limited human activity. We tracked the ocelot using a hand-held receiver and 3-element Yagi directional antenna (Communications Specialist, Inc., California, USA). As ocelots are both diurnal and nocturnal (Maffei and Noss, 2008), we alternated radiotracking sessions between day and night every two days, with two night-day sessions followed by two days off. Using a network of trails, we located the ocelot using triangulation up to 6 times/day assuming that the observations were independent (White and Garrott, 1990). We estimated home range using 95 % fixed kernel density estimate with least-squares cross validation and a smoothing factor of 500

(Worton 1989,Gitzen and Millspaugh, 2003). For each location we determined land cover (IDEAM *et al.,* 2007) and measured the distance of each location to the nearest stream or river and road (IDEAM *et al.,* 2007, National Imagery and Mapping Agency, 2009). We then generated random 200 locations from within the estimated home range and determined the same landscape attributes as for ocelot locations. We used binomial logistic regression to determine if ocelots selected distance to landscape features increases the probability of locating the ocelot compared to availability. We performed GIS analyses in ArcGIS 10.2 (Environmental Systems Research Institute, 2013) and logistic regression using Infostat with an alpha level of 0.05.

RESULTS

We monitored the female ocelot from 20 November 2010 to 20 January 2011 in two periods; we obtained 59 locations from November 20 to December 6 2010 and 41 locations from 31 December 2010 to 20 January 2011. The 95% fixed kernel home range estimate was 9.64 km^2. The ocelot was located more frequently in natural forests (45%), followed by agricultural areas (25%; Table 1, Figure 1). Probability of ocelot use increased in areas closer to rivers and as distance from roads increased (Table 2). Land cover did not significantly influence ocelot use probabilities.

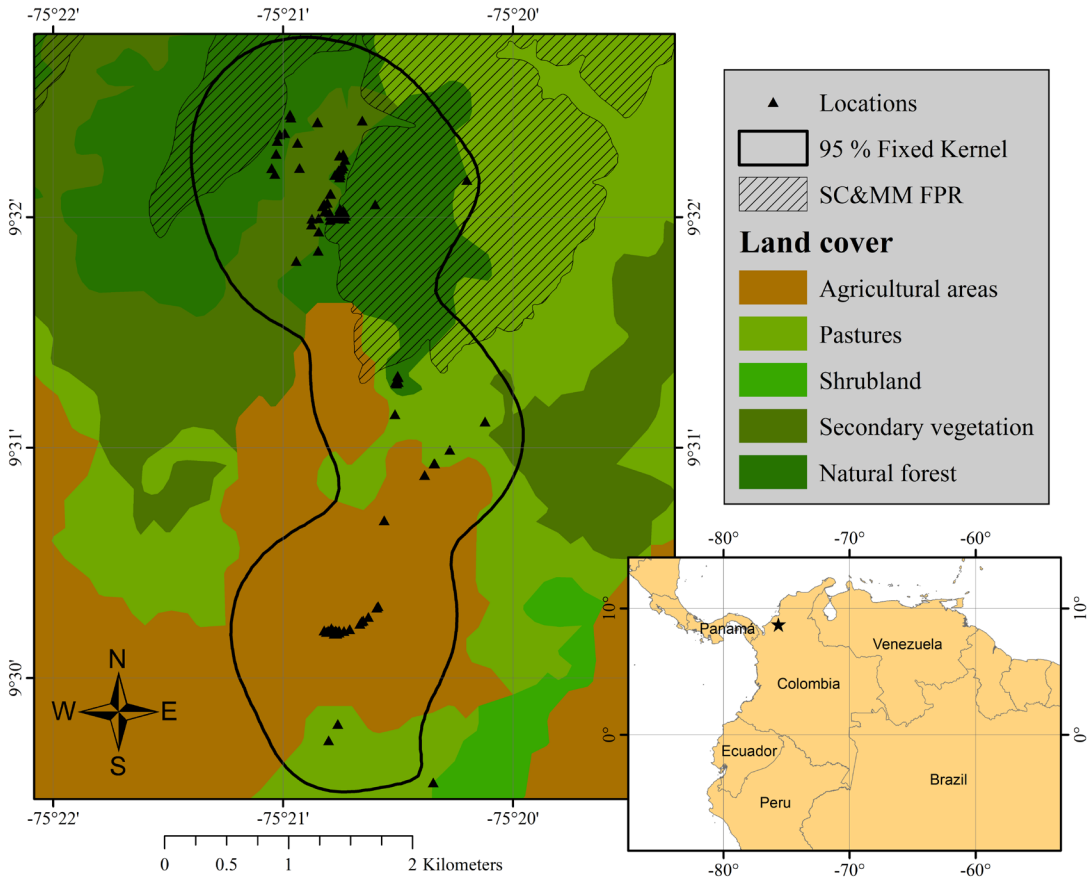

Figure1. Ocelot radio-telemetry locations and 95% fixed kernel home range in Sucre department, Colombia, November 2010-January 2011.

Table 1. Percent use and availability of land-covers by a female ocelot (n = 100 locations) in a fragmented landscape of Sucre department, Colombia.

Land cover	Use	Availability
Agricultural areas	25	10.7
Natural forests	45	38.4
Pastures	8	18.2
Secondary vegetation	21	32.7
Shrubland	1	0

Table 2. Logistic regression model for habitat use of a female ocelot in a fragmented landscape of Sucre department, Colombia.

Variables	Value	Standard Error	Odd Ratio	Wald X^2	p-value
Intercept	0.93122	0.26709	2.53759	12.15612	0.0005
Distance to rivers	-0.00089	0.00038	0.99911	5.33185	0.0209
Distance to roads	0.00091	0.00045	1.00091	4.12839	0.0422
Natural cover	-0.000019	0	1.00	no data	no data
Intervened cover	-0.0000075	0.000038	1	0.04	0.8418

DISCUSSION

This study represents the first data on ocelot home range in Colombia and provides insights on ocelot use of fragmented landscapes in the country. Land use change and deforestation in the Caribbean region of Colombia is a primary threat for biodiversity, a consequence of long-term unsustainable natural resource use eliminating otherwise continuous suitable habitat for felids (González-Maya *et al.,* 2013). As habitat decreases and becomes more isolated, understanding how wildlife use these fragmented landscapes represents one of the most critical issues in conservation biology (Daily *et al.,* 2003). Currently, most of the region has suffered of large carnivores´ extirpation (González-Maya *et al.,* 2013), therefore mesocarnivores, such as ocelot, may represent the most important predators in these ecosystems (González-Maya *et al.,* 2011), potentially playing key roles in trophic chains.

Ocelots in our study area seem to use intervened areas for their movements, however, still making extensive use of forested areas. Previous studies indicate ocelots can use open areas, usually at night (Nowell and Jackson, 1996; Maffei and Noss, 2008), but in general avoid these in order to prevent predation by large carnivores and because prey availability (Ludlow and Sunquist, 1987). Recent studies have suggested however that ocelot can use numerous habitats according to availability (Fusco-Costa *et al.,* 2010), including disturbed and undisturbed habitats (Kolowski and Alonso, 2010), but mostly preferring habitats that are structurally

complex (López González *et al.,* 2003); our results indicated that ocelots use every available habitat, also preferring those with forest structure, potentially highlighting the role of secondary growth as habitat for the species in these environments. Considering agriculture in the area is usually of small scale and for domestic production, the maintenance of tree cover within production units could facilitate movement of the species across this matrix.

The ocelot home range size was within the range of previous estimates, ranging from 2.3 km^2 in the United States (Haines *et al.,* 2006) and 1.64 km^2 in Peru (Emmons, 1988) to 25.25 km^2 in Belize (Dillon and Kelly, 2008). In terms of the relationship with landscape variables, our results coincide with previous statements about the spatial ecology of the species. Ocelots are considered to move on trails and roads (Nowell and Jackson, 1996; Di Bitetti *et al.,* 2006) and to prefer areas near water bodies (Ludlow and Sunquist, 1987; Emmons, 1988; López González *et al.,* 2003), however, our results indicate preference only for areas near water (i.e., rivers) but in general the individual avoided areas near roads. Nevertheless, our analyses included only secondary roads but no trails, so the individual likely avoided secondary roads but not necessarily small human trails.

Ocelots appear able to adapt to fragmented habitats, using all available land covers in this study, including open habitats probably for movement, especially in the absence of large predators. Our results suggest that although forested habitats are available and previously considered selected by the species (Nowell and Jackson, 1996), ocelots use the entire matrix of land covers. Nevertheless, there is still considerable use of forests, likely providing for food and shelter (Nowell and Jackson, 1996). Small scale agriculture and the presence of significant forest patches in this region have proved to be key for maintaining carnivore populations even in highly fragmented landscapes (Pineda-Guerrero *et al.,* 2015); therefore, ocelot use of agricultural areas can be related with the characteristics of these activities, including small-scale production and remaining tree cover. The association to water is also probably related with availability of prey and structured habitat (López González *et al.,* 2003), however for roads, this could mean significant movement barriers, even when ocelots use intervened areas, still avoid using areas surrounding roads.

Because most large predators are being extirpated from many areas in the Neotropics due to habitat loss and hunting (Nowell and Jackson, 1996), ocelots are becoming the top predators in many ecosystems (González-Maya *et al.,* 2011). Therefore, their ecology and habitat use in fragmented landscapes should be a priority topic for conservation planning as ocelots may become conservation surrogates as new key-stone and flagship species in many tropical landscapes.

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