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Spatial patterns of the margay (*Leopardus wiedii*; Felidae, Carnivora) at "El Cielo" Biosphere Reserve, Tamaulipas, Mexico

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Abstract

The margay (*Leopardus wiedii*) is classified as an endangered species in Mexico, and it is listed in Appendix I under CITES. Spatial ecology studies of margays are depauperate, with three previous studies consisting only of single radio-tracked individuals. The northeastern distributional limit for the margay is the "El Cielo" Biosphere Reserve (RBEC) in Tamaulipas, Mexico. From 2002–2004 and in 2008, we conducted an *in situ* project to evaluate the status and spatial ecology of the margay population at the RBEC. We used 20 Tomahawk live traps to capture nine margays (six males and three females). Margays were sedated with tiletamine-zolazepam at a mean dosage of 5 mg/kg, and fitted with VHF radio-collars. Mean home range size (95% minimum convex polygon) and core area (50% minimum convex polygon) for four males were 4.1 km^2 and 1.0 km^2, respectively. Data were insufficient to calculate female home ranges. Mean home range overlap between male margays was 29.5% (range: 4.8–55.6%). The quality of habitat of the RBEC and the absence of the usually sympatric ocelot (*Leopardus pardalis*) may explain the apparently high margay abundance observed in the study area. The RBEC supports the northeastern-most margay population in the Western Hemisphere and therefore has important conservation value in Mexico.

Keywords: home range; *Leopardus wiedii*; margay; Mexico; radio-telemetry.

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Introduction

The margay (*Leopardus wiedii* Schinz, 1821), one of the least known wild cat species, is similar in appearance to the larger sympatric ocelot (*Leopardus pardalis* Linnaeus, 1758; Nowell and Jackson 1996). Unlike the ocelot, the margay is rare throughout its range, and there is little information on its distribution and ecology (Burton and Pearson 1988, Sunquist and Sunquist 2002). Margay populations have suffered from habitat destruction and fur exploitation (Kitchener 1991). The margay was upgraded to CITES Appendix I in 1989 (Fuller et al. 1987), and is considered endangered in Mexico (Ley General del Equilibrio Ecológico, Norma Ecológica 059-2001; SEMARNAT 2001). According to the IUCN Red List, the margay population in Tamaulipas, Mexico, is considered susceptible to disease outbreaks (Payan et al. 2008), and the "El Cielo" Biosphere Reserve (RBEC) in Tamaulipas is considered the northern distribution limit (Leopold 1959).

Spatial ecology studies of margays are depauperate with three previous studies consisting only of single radio-tracked individuals. Konecny (1989) captured two males and radio-collared one immature individual during a 21-month study in Belize. This individual was radio tracked for 6 months and exhibited a home range of 10.9 km^2; however, there were large patches of open areas that were unused or avoided within this home range. Additionally, one male (15.9 km^2) and one female (20 km^2) margay were radio-tracked in Iguacu, Brazil and Taquari, Brazil, respectively; although the habitat quality and home range estimators used are unclear (*in* de Oliveira et al. 2010). Margay distribution in Mexico has been studied using cameras in Sonora (Gallo and Navarro 2002), Chamela-Cuixmal Biosphere Reserve, Jalisco (Domínguez and Ceballos 2005) and the Biosphere Reserve in Tehuacán-Cuicatlan, Oaxaca (Botello et al. 2006). Additionally, a recent camera trap study in central Mexico estimated margay density at 12.1 per 100 km^2 (López-Hernández 2010).

Our study is the only radio telemetry study conducted to examine the spatial ecology of multiple margays. Furthermore, because the RBEC represents the northern distribution of the margay, it was critical to study margay ecology to assist conservation strategies in this unique region (Lebreton et al. 1992, Reid et al. 2002). The objectives of our study were to measure margay morphometrics, spatial ecology and activity patterns.

Materials and methods

Study area

The study occurred in the RBEC (23°03′08.2″ N, 99°13′54.2″ W) in southeastern Tamaulipas, Mexico (Figure 1). The RBEC

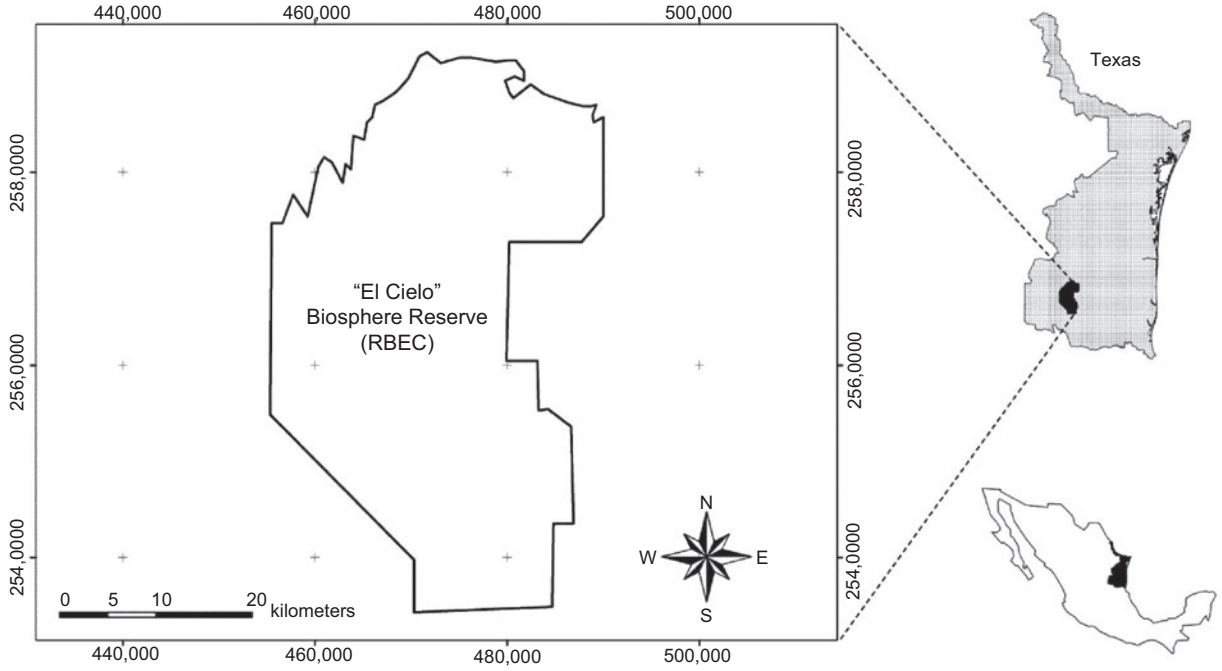

Figure 1 Location of the "El Cielo" Biosphere Reserve (RBEC) in Tamaulipas, Mexico.

encompasses 1445 km^2 and is managed by the state government of Tamaulipas. The size of our study area was 6.4 km^2.

The RBEC is important as a transition zone where the flora, fauna and climate are mostly tropical, but where temperatures at higher elevations are similar to temperate environments (Hooper 1953). The wet season occurs from May to October; the annual mean temperature is 22.8°C, and annual precipitation is 1852 mm (Puig and Bracho 1987).

Five vegetation types occur in the RBEC (Puig and Bracho 1987) including tropical deciduous forest that ranges from 200- to 800-m elevation, with the most common plant species being *Bursera simaruba, Croton niveus, Miradanceltis monoica* and *Brosimum alicastrum.* Cloud forest is located between 801-m and 1400-m elevation, and some characteristic plant species are *Liquidambar styraciflua, Quercus sartorii, Clethra pringlei* and *Magnolia schiedenea*. Oak-pine forest is situated from 1401- and 1800-m elevation with *Quercus sororia, Q. glaucenses, Pinus montezumae* and *P. teocote.* Oak-pine and cloud forests are dominant in the reserve. The chaparral (xeric thornshrub) occurs around 1600-m elevation in the more arid zone of the RBEC, and pine forest occurs over 1800-m elevation. The study was conducted below 1000 m in the cloud and tropical forests, and in the ecotone between these two vegetation types. In addition, fruit tree plantations occur within the study area in the vicinity of small villages.

Capture method

Seven trapping sessions for margays were undertaken in this study: June 2001, February, June and November 2002, April and December 2003 and December 2008. Each trapping session lasted 7–13 days. Margays were captured using 20 wire Tomahawk® Live Traps (107×50×40 cm; Tomahawk, Hazelhurst, WI, USA), with an attachment containing a live chicken as an attractant. Captured margays were immobilized with a pole syringe containing tiletamine-zolazepam (Zoletil 50®, Virbac; Guadalajara, Jalisco, Mexico) at a mean dosage of 5 mg/kg (Caso et al. 2005). The gender, age, weight and body measurements were recorded for each individual. Age was based on tooth eruption, tooth wear, body size and the experience of the authors in aging wild felids from previous studies (Ferreras et al. 2004, Grassman et al. 2005). We multiplied the number of traps by the number of nights divided by the number of total captures to calculate trapping success (Caso 1994).

Each margay was fitted with a VHF radio-collar weighing 25 g (Advanced Telemetry Systems; Isanti, MN, USA) that emitted a constant pulse and contained a mortality sensor. Margays were released at the capture site after recovery from the effects of immobilization (Caso et al. 2005).

We attempted to locate each radio-collared margay 20 times per month for home range estimation. Telemetry was conducted diurnally during different times of the day with a minimum of 24-h separation for independence of locations. Portable telemetry equipment was used to track nine radio-collared individuals. For each location, two or three bearings were taken from different fixed receiver stations previously established with a hand-held global positioning system (Lowrence®; Tulsa, OK, USA). Radio telemetry locations were evaluated with the program LOCATE II® (Tatamagouche, NS, Canada) to rank the quality of the angle and were then analyzed with the program CALHOME® (Champaign, IL, USA). All locations which included any telemetry stations within the LOCATE II ellipse error were excluded from data analyses.

Home range area curves were generated for each margay to determine if home range size had reached an asymptote. The 95% and 50% minimum convex polygon (MCP) defined home range and core area sizes, respectively (Mohr and Stumpf 1966, Caso 1994). The MCP estimator was used as the primary method for home range analysis because it is the most common estimator used in carnivore studies. For comparative purposes, the 95% fixed kernel estimator (FK) was used as well. We estimated home range overlap as percent overlap between males with the ARC GIS® program (ESRI, Redlands, CA, USA; Dillon and Kelly 2008). We monitored two individuals hourly for 24 h to determine activity patterns (Caso 1994). Margay activity was measured by a change in the volume of the received radio signal. Activity was recorded every hour, and hourly movement distance between locations was measured for each margay using the CALHOME® program.

Results

We captured nine margays (6 M; 3 F; 7 recaptures) with a mean capture rate of 804 trap nights/capture, including recaptures. Mean adult male margay body length was 89.1 cm (range: 81.5–98 cm). Both adult females had a body length of 86 cm, whereas the only subadult female captured measured 84.5 cm in body length (Table 1). Adult males had a mean weight of 2.8 kg (range of 1.3–4 kg); and the only subadult male weighed 2.3 kg. The two adult females weighed 2.0 kg, whereas a subadult female weighed 1.2 kg.

Due to the natural mortalities of four individuals and two radio-collar failures, we obtained home range estimates for four male margays. The mean MCP home range value for males was 4.1 km^2 ($\underline{s}$=2.16); the minimum home range was 1.2 km^2, and the maximum was 6.0 km^2 (Figure 2, Table 2). The mean MCP core area size for males was 1.0 km^2 ($\underline{s}$=0.67); the minimum core area was 0.3 km^2, and the maximum was 1.8 km^2 (Figure 3, Table 2). The mean FK home range size was 10.6 km^2 (Figure 4, Table 2).

Overlapping home ranges among the four male margays were extensive with margay M6 and M1 sharing 37.3% (2.0 km^2) area and less between margay M1 and M3 with 4.8% (0.18 km^2) overlap. Average overlap was 29.5%.

We obtained limited activity information for one male and one female. Margays were nocturnal with the male margay showing two activity peaks at 1800 and 0100 h and the female margay showing increased activity at 0200, 0400, 1800 and 2100 h.

Live trapping resulted in the capture of other carnivores including 14 gray foxes (*Urocyon cinereoargenteus* Schreber, 1775), three raccoons (*Procyon lotor* Linnaeus, 1758), one coatimundi (*Nasua narica* Linnaeus,1766) and one opossum (*Didelphis virginiana* Allen, 1900). Ocelots, which are often sympatric with margays, may have occurred in the study area based on historical records (Leopold 1959); however, our live trapping results combined with hunter interviews indicated that this species was absent in our study area.

Discussion

Our trapping results suggest margay abundance in the RBEC was high during our study period. As an example, Konecny (1989) trapped two margays during 21 months of field work in Belize, whereas we captured nine individuals during 2.5 months of cumulative field work within a 3-year period. In addition, we found a dead subadult female margay within this area that we did not capture.

We trapped in two types of vegetation, tropical forest and cloud forest, and captured margays in both types. Of the four resident margay males radio-collared in this study, three were captured in tropical forests and one was captured in cloud forest. These individuals based their respective home ranges primarily within the forest type in which they were captured. Vargas and Huerta (2001) reported that the specific distribution of the margay is only within cloud forests. Conversely, other authors have reported that margays use deciduous evergreen (Bisbal 1989, de Oliveira 1998, Nowak 1999), tropical and subtropical forests (Kleiman and Eisenberg 1973, Konecny 1989).

Margay morphometrics in this study were similar to those reported by Kitchener (1991), Hall (1981) and Konecny

Table 1 Body measurements (cm) and weights (kg) of adult male and female margays (*Leopardus wiedii*) captured in the RBEC, Tamaulipas, Mexico.

Margay ID	Sex	Age	Total length	Body length	Tail length	Head circumference	Hind foot	Weight	Scrotal circumference
M1	Male	Adult	81.5	52.5	29	20.6	11	3.2	2.7
M2	Female	Adult	86	52	34	21	11	2.0	
M3	Male	Adult	89	55	34	23	10.7	3.5	2.7
M4	Female	Sub-adult	84.5	53	31.5	19	10	1.2	
M5	Female	Adult	86	54	32	19	10.7	2.0	
M6	Male	Adult	98	62	36	22.5	11.7	2.3	3
M7	Male	Adult	88	55	33	21.3	10.2	1.3	2.2
M8	Male	Sub-adult	84	46.3	37.7	19	11.1	2.3	
M9	Male	Adult	–	–	–	–	–	4.0	
SE			4.9	4.3	2.7	1.5	0.5	0.9	0.3
Mean			86	53.5	33.5	20.8	10.8	2.4	2.6

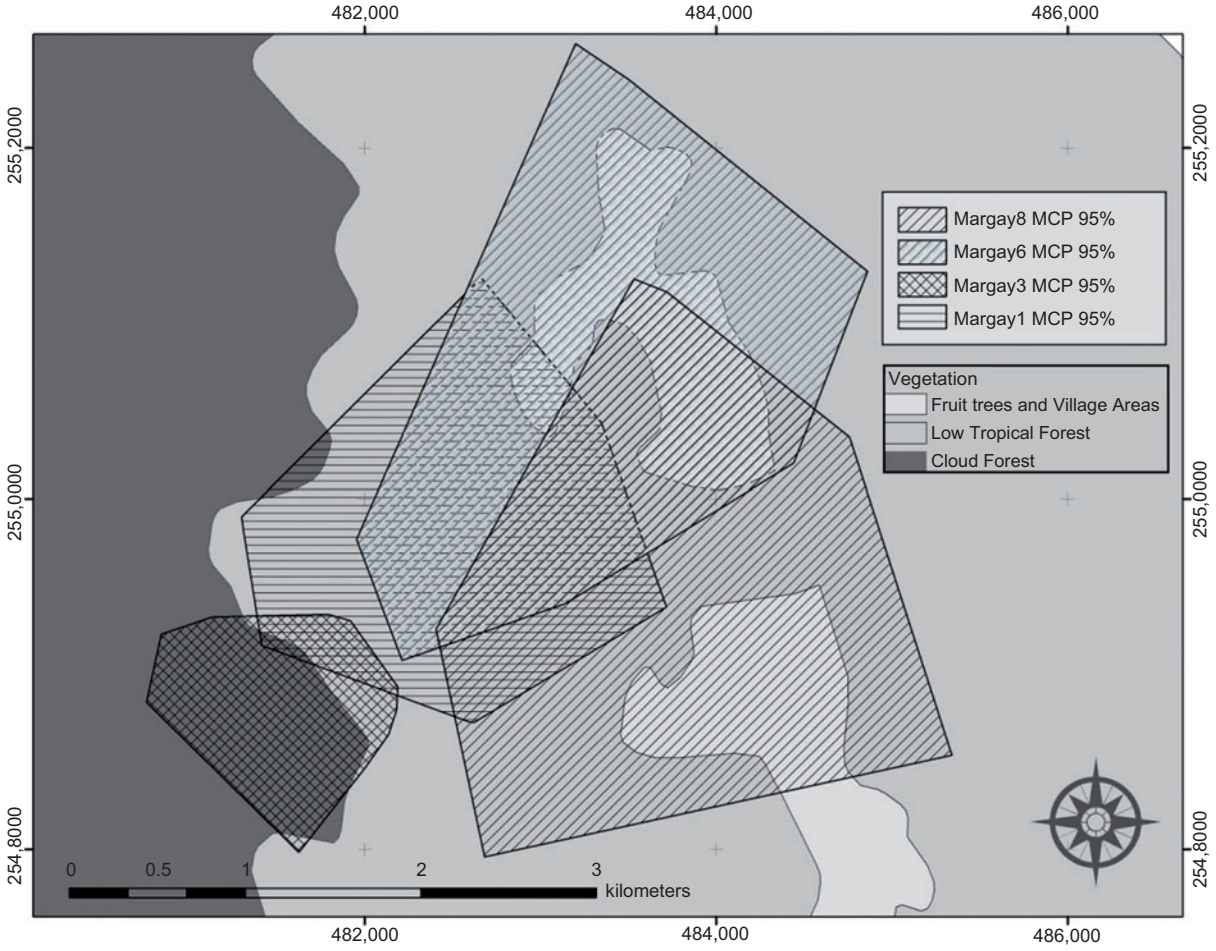

Figure 2 Home range sizes (95% minimum convex polygon) of four radio-collared male margays (*Leopardus wiedii*) in the RBEC, Tamaulipas, Mexico.

(1989). However, de la Rosa and Nocke (2000), Nowak and Paradiso (1983), de Oliveira (1998), Eisenberg and Redford (1999) and Nowak (1999) reported smaller body sizes (length and weight). This variation is likely due to differences between subspecies. The smaller sizes reported were for margays from Central America, whereas this study sampled the northeastern-most distribution limit of margays (Leopold 1959). Whereas, adults margays from our study area had a mean weight of 2 kg for females and 2.8 kg for males, other authors recorded heavier average weights of 3.3 kg (de Oliveira and Cassaro 2005) and 3.2 kg (Einsenberg and Redford 1999, Nowak 1999) for margays in South America. Margays captured in this study were lighter than expected, although in 2008 we did capture a 4.0-kg male margay.

Table 2 Home range and core area sizes (95% and 50% minimum convex polygons, respectively) of four radio-collared male margays (*Leopardus wiedii*) in the RBEC, Tamaulipas, Mexico.

Animal ID	No. of locations	MCP 95%	MCP 50%	FK 95%
M1	25	3.7	1.8	14.5
M3	84	1.2	0.3	2.3
M6	23	5.5	1.4	14.2
M8	47	6.0	1.4	11.4
Mean		4.1	1.2	10.6
SE		2.1	0.7	5.7

Two captured females (M2 and M4) and two males (M3 and M7) were captured in poor physical condition with low body fat as assessed by a veterinarian (e.g., protrouding ribs and hip bones). M7 died shortly after capture, was necropsied and found to have an ulcerated stomach and diseased lungs, which may have contributed to his death. Females M2 and M4 were found dead after 2 months of radio-tracking. Conversely, male M3 lived over 2 years beyond his initial capture date. Additionally, the discovery of a dead uncollared female margay may indicate margays were under significant environmental stress. Causes of environmental stress are unclear and warrant investigation.

Information about home range sizes of margays is lacking. Our study was the only multi-cat study of margays using radio-telemetry. Recently, a study investigating margay density, habitat use and activity patterns was completed in central Mexico using camera trapping (López-Hernández 2010). López-Hernández (2010) found a density of 12.1 individuals per 100 km^2, and reported that margays preferred pine-oak forest.

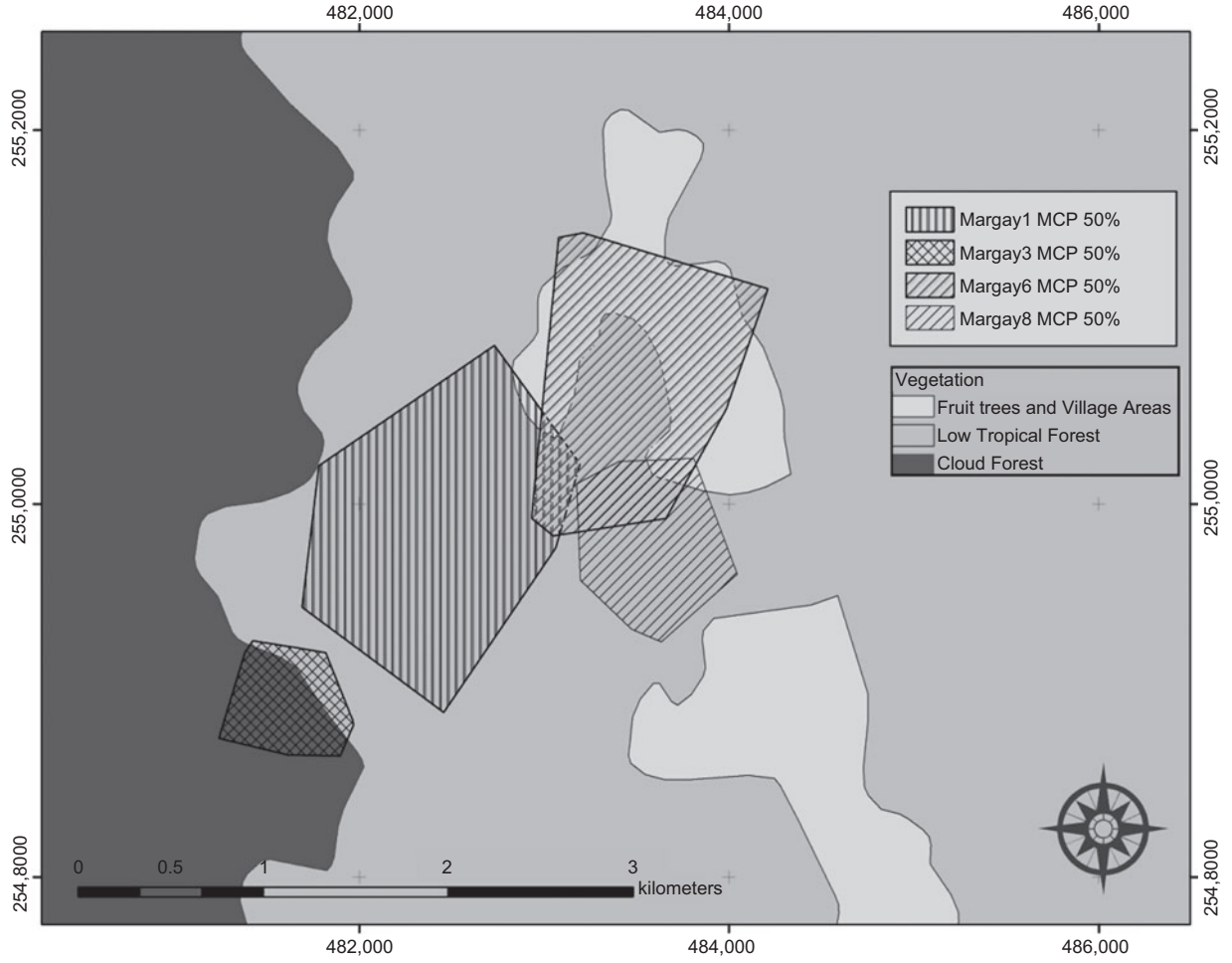

Figure 3 Core area sizes (50% minimum convex polygon) of four radio-collared male margays (*Leopardus wiedii*) in the RBEC, Tamaulipas, Mexico.

The home range cumulative area curve of M6 (n=23 locations) did not reach an asymptote; however, based on the results of the other three margays where the home range area curve reached an asymptote at around 25 locations, it seems reasonable to conclude that the home range of M6 may have been close to reaching an asymptote. Our mean MCP home range estimate of 4.0 km^2 for male margays was considerably smaller than that reported by Konecny (1989) of 10.9 km^2 (MCP) for a subadult male. RBEC margay home ranges were also smaller than that found for one male (15.9 km^2) and one female (20 km^2) margay from Iguacu, Brazil and Taquari, Brazil, respectively, although the habitat quality and home range estimators used in these studies are unclear (*in* de Oliveira et al. 2010). Konecny (1989) used permanent radio stations, and the angle between the stations for triangulation was sometimes poor (<30 degrees), which may have yielded inaccurate locational data. However, the primary cause of the smaller home ranges in this study was likely habitat quality. El Cielo consisted of a protected, intact forest complex where margay ecological requirements may have been met within smaller home ranges compared to the more disturbed habitat types of the other studies.

We observed a high degree of home range overlap between male margays. The home ranges of males usually do not overlap substantially in many small cat species (Sunquist and Sunquist 2002); however, the overlap expressed may have indicated weak territoriality as seen for leopard cats (*Prionailurus bengalensis* Kerr, 1792) in Thailand (Grassman et al. 2005) and Malaysia (Rajaratnam 2000), and with bobcats (*Lynx rufus* Schreber, 1777) in Illinois (Nielsen and Woolf 2001). In these studies, the core areas remained exclusive, similar to what was observed in the home ranges of this study. Males M3, M6 and M8 had small core areas relative to their home ranges; whereas M1 had a core range that was about half the size of its home range.

Activity data obtained in this study is consistent with that from a camera-trapping study (López-Hernández 2010) that indicated primary activity between 2100 to 0300 h. Margay nocturnal activity also agrees with that reported by Petersen (1977) and Konecny (1989).

We experienced radio-collar failures and were therefore unable to collect sufficient numbers of radio-locations for some individuals. Additionally, the ruggedness of the terrain made it difficult to collect radio-telemetry data; however,

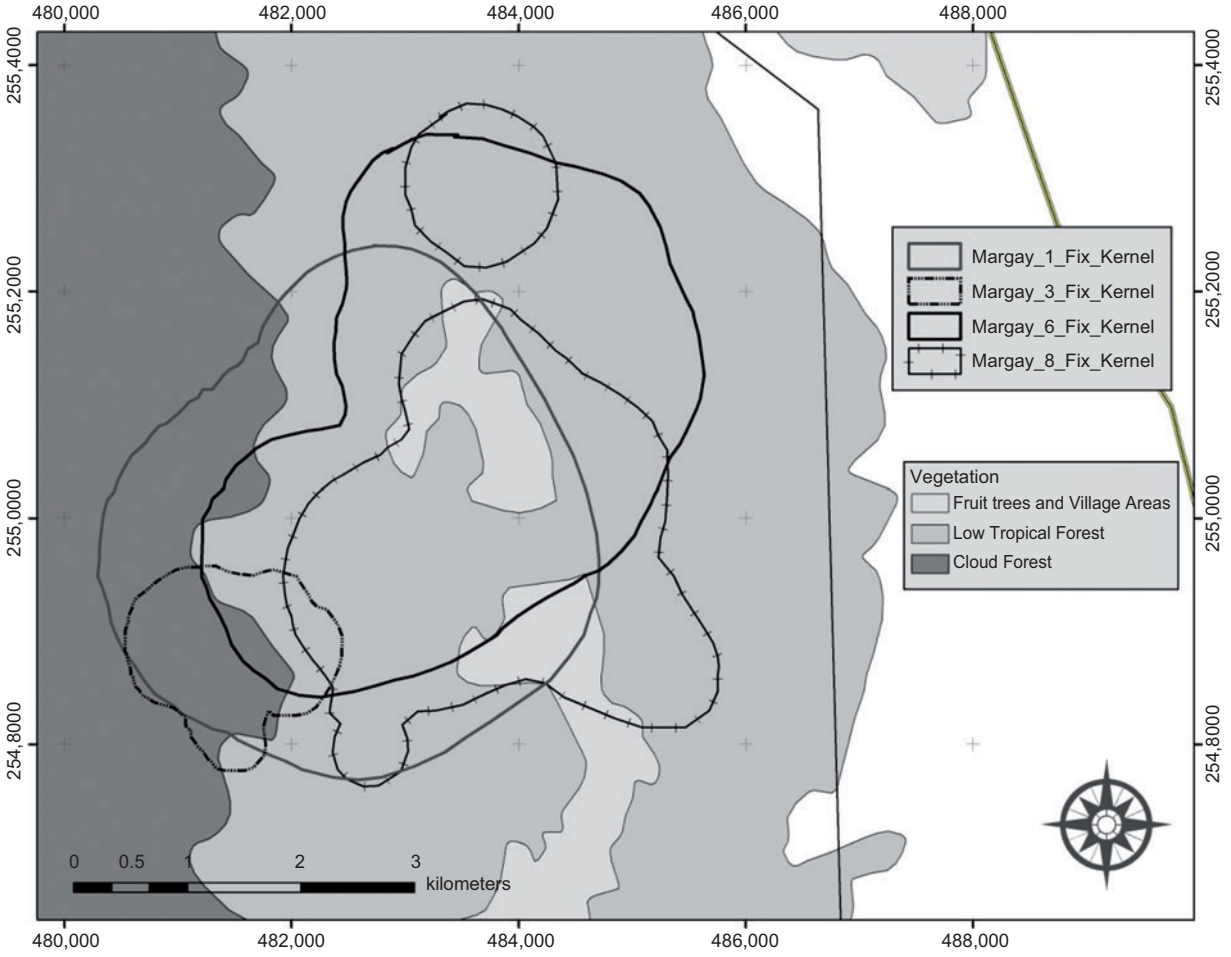

Figure 4 Home range sizes (95% fixed kernel) of four radio-collared male margays (*Leopardus wiedii*) in the RBEC, Tamaulipas, Mexico.

we obtained home range values for almost all the radio-collared males (four of six individuals). For female M2, 10 radio-locations were collected over 2 months, showing an area of use about 0.72 km^2. For female M5, we were only able to collect activity data for 7 days due to radio collar failure shortly after this cat was radio-collared. The third captured female margay was a subadult too young to radio-collar.

Compared with other areas of Mexico that have cloud forests and substantial human impacts, the RBEC has minimal human impacts. Although small human communities occur in the RBEC, their disturbance appears minimal. One of the main activities in the area is the harvest of palmilla (*Chamaedorea radicalis*); however, the impact on margay habitat is negligible because the harvesters ("palmilleros") use the area for a short period of time and their activities cause little disturbance. Additionally, there are extensive areas of the RBEC that have not been disturbed, which should provide good habitat for the margay.

Margays are susceptible to deforestation and destruction of their habitat (Tewes and Schmildly 1987); thus, the RBEC represents an important area harboring an apparently high density of margays. Primary margay habitat of cloud forest and tropical forest occupies just 17% (250 km^2) of the RBEC total area of 1445 km^2. Our study area occupied 6.4 km^2, or just 2.5% of the total amount of good margay habitat in the RBEC, yet we documented a minimum of 10 margays. Additionally, the absence of ocelots in the study area may have allowed for conditions benefiting margay population size. This scenario may have followed a phenomenon dubbed the "ocelot effect" by de Oliveira et al. (2010), where decreases in ocelot densities in a study site in southern Brazil resulted in increases in smaller sympatric felids (including margays) due to reduced intraguild competition. Thus, based on the number of individuals captured and observed in our small study area, combined with an absence of ocelots, it is likely that the RBEC harbors a substantial and important margay population.

This study was the first noteworthy research on the spatial ecology of several overlapping margays using radio telemetry. Furthermore, the RBEC seems to support a margay population that has important conservation value because the location represents the fringe of its northern range. Future research should focus on monitoring this population and, in particular, on the potential impact that diseases or prey availability may have on margay body condition and subsequent survival.

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References

Bisbal, F.J. 1989. Distribution and habitat association of the carnivores in Venezuela. In: (K.H. Redford and J.F. Eisenberg, eds.) Advances in neotropical mammalogy. Sandhill Crane Press, Gainesville, FL. pp. 339–362.

Botello, F.P., M. Illoldi-Rangel, M. Linaje and V. Sánchez-Cordero. 2006. Primer registro del tigrillo (*Leopardus wiedii* Sahinz, 1821) y del gato montés (*Lynx rufus* Kerr, 1792) en la Reserva de la biosfera de Tehuacan-Cuicatlan, Oaxaca, México. Acta Zool. Mexicana. 22: 135–139.

Burton, J.A. and B. Pearson. 1988. The Collins guide to the rare mammals of the world. Stephen Green Press, Lexington, MA. pp. 240.

Caso, A. 1994. Home range and habitat use of three neotropical carnivores in northeast Mexico. M.S. Thesis, Texas A&M University-Kingsville, Kingsville, TX. pp. 87.

Caso, A., S. Carvajal-Villarreal, P. Downey and A. Moreno. 2005. Técnicas de captura y manejo del margay (*Leopardus wiedii*) en la Reserva de la Biosfera El Cielo. In: (G. Sánchez-Ramos, P. Reyes-Castillo and R. Dirzo, eds.) Historia natural de la reserva de la Biosfera "El Cielo", Tamaulipas, México. Universidad Autónoma de Tamaulipas. Impreso en Hong Kong. pp. 538–542.

de la Rosa, C.L. and C.C. Nocke. 2000. A guide to the carnivores of Central America. University of Texas Press, Austin, TX. pp. 226.

de Oliveira, T.G. 1998. *Leopardus wiedii*. Mammal Species. 579: 1–6.

de Oliveira, T.G. and K. Cassaro. 2005. Guia de campo dos felinos do Brasil. Instituto Pró-Carnívoros/Fundação. Parque Zoológico de São Paulo/Sociedade de Zoológicos do Brasil/Pró-Vida Brasil, São Paulo, Brazil. pp. 80.

de Oliveira, T.G., M.A. Tortato, L. Silveira, C.B. Kasper, F.D. Mazim, M. Lucherini, A.T. Jácomo, J.B.G. Soares, R.V. Marques and M.E. Sunquist. 2010. Ocelot ecology and its effect on the small-felid guild in the lowland neotropics. In: (D.W. Macdonald and A.J. Loveridge, eds.) Biology and conservation of the wild felids. Oxford University Press, Oxford, New York. pp. 559–580.

Dillon, A. and M. Kelly. 2008. Ocelot home range, overlap and density: comparing radio telemetry with camera trapping. J. Zool. 275: 391–398.

Domínguez, C. and G. Ceballos. 2005. Un registro notable del tigrillo (*Leopardus wiedii*) en la Reserva de la Biosfera Chamela – Cuixmala, Jalisco. Rev. Mex. Mastozool. 9: 146–149.

Eisenberg, J.F. and K.H. Redford. 1999. Mammals of the neotropics. Vol. 3: The central neotropics, Ecuador, Peru, Bolivia, Brazil. University of Chicago Press, Chicago, IL. pp. 609.

Ferreras, P., M. Delibes, F. Palomares, J.M. Fedriani, J. Calzada and E. Revilla. 2004. Proximate and ultimate causes of dispersal in the Iberian lynx *Lynx pardinus*. Behav. Ecol. 15: 31–40.

Fuller, K.S., B. Swift, A. Jorgensen and A. Brautigam. 1987. Latin American wildlife trade laws. 2nd rev. ed. WWF, Washington DC. pp. 354.

Gallo, J.P. and C. Navarro. 2002. Range extension of margay in northwestern Mexico. Southwest. Nat. 47: 635–636.

Grassman Jr., L.I., M.E. Tewes, N.J. Silvy and K. Kreetiyutanont. 2005. Spatial organization and diet of the leopard cat (*Prionailurus bengalensis*) in north-central Thailand. J. Zool. (London) 266: 45–54.

Hall, E.R. 1981. Mammals of North America. 2nd ed. John Wiley, New York. pp. 1355.

Hooper, E.T. 1953. Notes on mammals of Tamaulipas, Mexico. Occasional Papers of the Museum of Zoology, University of Michigan. Vol. 544. pp. 1–12.

Kitchener, A. 1991. The natural history of the wild cats. Academic Press Ltd., London. pp. 238.

Kleiman, D.G. and J.F. Eisenberg. 1973. Comparisons of canid and felid social systems from an evolutionary perspective. Animal Behav. 21: 637–659.

Konecny, M.J. 1989. Movements patterns and food habits of four sympatric carnivore species in Belize, Central America. In: (K.H. Redford and J.F. Eisenberg, eds.) Advances in neotropical mammalogy. Sandhill Crane Press, Gainesville, FL. pp. 243–264.

Lebreton, J., D.K.P. Burnham, J. Clobert and D.R. Anderson. 1992. Modeling survival and testing biological hypothesis using marked animals: case studies and recent advances. Ecol. Monogr. 62: 67–118.

Leopold, A.S. 1959. Wildlife of Mexico. University of California Press, Berkeley, CA. pp. 568.

López-Hernández, L.D. 2010. Abundancia y patrón de actividad de *Leopardus wiedii* en la Sierra Nanchititla, México. Tesis de Licenciatura para obtener el título de Biólogo. Facultad de Ciencias. Universidad Autónoma del Estado de México, Toluca. pp. 45.

Mohr, C.O. and W.A. Stumpf. 1966. Comparison of methods for calculating areas of animal activity. J. Wildlife Manag. 30: 293–304.

Nielsen, C.K. and A. Woolf. 2001. Spatial organization of bobcats (*Lynx rufus*) in southern Illinois. American Midland Naturalist. 146: 43–52.

Nowak, R.M. 1999. Walker's Mammals of the world. 6th ed. The Johns Hopkins University Press, Baltimore, MD. pp. 1936.

Nowak, R.M. and J.L. Paradiso. 1983. Walker's Mammals of the world. 4th ed. The John Hopkins University Press, Baltimore, MD. pp. 1362.

Nowell, K. and P. Jackson. 1996. Wild cats: status survey and conservation action plan. IUCN, Gland, Switzerland. pp. 382.

Payan, E., E. Eizirik, T. De Oliveira, R. Leite-Pitman, M. Kelly and C. Valderrama. 2008. *Leopardus wiedii*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. <www.iucnredlist.org>. Accessed on 08 March 2011.

Petersen, M.K. 1977. Courtship and mating patterns of margays. In: (R. Eaton, ed.) The world's cats. Vol. 3. Biology, behavior and management of reproduction. Carnivore Resource Institute, University of Washington, Seattle, WA. pp. 22–35.

Puig, H. and R. Bracho. 1987. El bosque mesofilo de montaña de Tamaulipas. Instituto de Ecología, A. C. México D. F. pp. 186.

Rajaratnam, R. 2000. Ecology of the leopard cat (*Prionailurus bengalensis*) in Tabin Wildlife Reserve, Sabah, Malaysia. Ph.D. Dissertation, Universiti Kebangsaan Malaysia, Bangi, Malaysia. pp. 249.

Reid, J.M., L.S. Mills, J.B. Dunning Jr., E.S. Menges, K.S. McKelvey, R. Frye, S.R. Beissinger, M.C. Anstett and P. Miller. 2002. Emerging issues in population variability analysis. Conserv. Biol. 16: 7–19.

SEMARNAT (Secretaría de Medio Ambiente y Recursos Naturales). 2001. Norma Oficial Mexicana NOM-059-ECOL-2001, que determina las especies y subespecies de flora y fauna silvestres, terrestres y acuáticas y las sujetas a protección especial y que establece especificaciones para su publicación. Diario Oficial de la Nación. 438: 2–60.

Sunquist, M. and F. Sunquist. 2002. Wild cats of the world. University of Chicago Press, Chicago, IL. pp. 462.

Tewes, M.E. and D.J. Schmildly. 1987. The neotropical felids: jaguar, ocelot, margay and jaguarundi. In*:* (M. Novak, J.A. Baker, M.E. Obbard and B. Malloch, eds.) Wild furbearer management and conservation in North America. Ministry of Natural Resources. Ontario, Canada. pp. 697–712.

Vargas, C.J. and A.H. Huerta. 2001. Distribución latitudinal de la mastofauna en la Reserva de la Biosfera “El Cielo”, Tamaulipas, México. Acta Zool. Mexicana. (n. s.) 82: 83–109.

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