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La Portada

Guanaco (*Lama guanicoe*) es una de las especies más representativas de las regiones andinas de América del Sur desde Bolivia-Perú hasta Argentina-Chile. Fotografía tomada en Torres del Paine, Chile, considerada como una de las regiones más hermosas del mundo. En esta región es frecuente encontrar grandes manadas de guanacos en condiciones silvestres. (Fotografía de Sergio Ticul Álvarez Castañeda).

Nuestro logo "Ozomatli"

El nombre de "Ozomatli" proviene del náhuatl se refiere al símbolo astrológico del mono en el calendario azteca, así como al dios de la danza y del fuego. Se relaciona con la alegría, la danza, el canto, las habilidades. Al signo decimoprimero en la cosmogonía mexica. "Ozomatli" es una representación pictórica de los mono arañas (*Ateles geoffroyi*). La especie de primate de más amplia distribución en México. " Es habitante de los bosques, sobre todo de los que están por donde sale el sol en Anáhuac. Tiene el dorso pequeño, es barrigudo y su cola, que a veces se enrosca, es larga. Sus manos y sus pies parecen de hombre; también sus uñas. Los Ozomatin gritan y silban y hacen visajes a la gente. Arrojan piedras y palos. Su cara es casi como la de una persona, pero tienen mucho pelo."

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Therya

El objetivo y la intención de *THERYA* es ser una revista científica para la publicación de artículos sobre los mamíferos. Estudios de investigación original, editoriales, artículos de revisión y notas científicas son bienvenidas.

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Letter to the editor

Molecular ecology and phylogenetic systematics: Approaches to the conservation genetics of mammals

Mexico is considered as the fifth largest country in terms of global diversity; this attribute is linked to the heterogeneity of environments throughout the territory. The Mexican biota has many topics of interest to address, it only requires choosing a botanical or zoological group or any geographical region, but, above all, an academic question to answer. However, what does still remain to be known and understood? More than 5,000 species of mammals are known in the world, which possess biological, morphological, social, and reproductive adaptations that allow them to live in virtually all types of environments. At the global level, Mexico ranks third in terms of mammal diversity, with approximately 493 species described to date, in the understanding that the recognition, study and validity of species in natural environments are aspects not yet addressed.

With the aim to study and measure the diversity of mammal species, various topics and levels of ecological, geographical and genetic organization have been addressed. For this reason, a greater level of comprehensive and dynamic knowledge is required that allows the interconnection of the biodiversity components (ecological, biological and genetic elements). A core attribute of biodiversity is genetic diversity, in addition to evolutionary processes (mutations, migrations, gene flow, sexual reproduction, horizontal gene transfer, etc.). Therefore, the genetic component has been a re-valued tool used primarily in systematic biology. It is for this reason that disciplines such as molecular ecology and phylogenetic systematics have contributed to the generation of knowledge about the changes in the genetic structure of species and populations, with DNA- or RNA-based molecular genetic markers (proteins, sequences) as extremely useful tools.

The phylogenetic or cladistic systematics contributes to the interpretation of genealogical relationships between species and biological groups, supported on the similarities derived. The cladistic analysis is a biological classification system that groups together organisms according to their evolutionary relationships, being useful to resolve phylogenies. It is in the 1990s when there is a generation of biologists (including mammalogists) interested in using innovative tools (molecular markers, genetic and statistical algorithms) to understand ecological and evolutionary processes. Molecular techniques are evolving rapidly and have become supplementary tools in Biology, focusing on 1) phylogeny and phylogenetics; 2) evolutionary processes; 3) gene regulation and development analysis. 4) conservation genetics.

At the beginning of the 21st century there was an increase in studies focused on integrative taxonomy with the use of molecular tools, leading to the development of the information regarding the genetic library of the biota. The generation of bar codes (standardized DNA fragment to identify the species of all living organisms. In the case of animals, a fragment of the cytochrome oxidase I [COI], mitochondrial gene is used). It is worth remembering that the properties of mitochondrial DNA make it a marker with unique features, such as how to be inherited through the mother; a high mutation rate, which implies nucleotide substitutions; presents no genetic recombination; it is neutral; the distribution of haplotypes (sets of alleles that come from a single chromosome) is more influenced by demographic events in the history of the population through natural selection; it is amplified in a relatively simple way.

The emergence of multidiciplinary and international initiatives (www.barcodeoflife.org) focused on the generation of genetic information that will help to set the biota database at a global level. These initiatives have focused mainly on mega-diverse countries, so that Mexico could not be excluded, naming it as a BIOTRON node based on its biotic diversity and its potential to generate genetic libraries (www.boldsystems.org).

As a result of this project, there are currently a total of some 68,000 public records of mammal specimens with bar codes worldwide. It regards the information produced by 167 countries, highlighting the importance of 185 Scientific Collections, repositories of mammal specimens of study. The region that stand out for the entry of records is Latin America, although there is representation of countries from different continents (Table 1).

The groups of mammals with the largest number of records with genetic codes are primates (22,356), with Russia as the country that has best documented this group. In second place, chiropterans, with 20,726 records, with the Cooperative Republic of Guyana as the country with the highest contribution to genetic records. The third re-presentative group is rodents, with 15,005 records, where Mexico has included the largest number of records (Table2),

Table 1. Number of mammal records published in the website www.boldsystems.org (as of 24 January 2017). The number of orders, families and species by country is shown.

Countries	Records	Orders	Families	Species
Guyana	7,229	8	26	171
Mexico	5,067	11	20	109
Canada	3,574	10	27	116
Russia	2,478	8	15	99
Ecuador	2,053	8	17	112
Suriname	1,933	4	13	108
China	1,896	10	25	172

mostly belonging to the rodent families Heteromyidae and Cricetidae.

At the national level, some linking efforts have been directed to produce genetic information of mammal species; an example is the CONACyT "Red Temática" named “Barcode of Life in Mexico” (www.mexbol.org). Public information is currently available of more than 5,000 records of Mexican mammal species, including 11 orders (Rodentia, Chiroptera, Lagomorpha, Didelphimorphia, Carnivora, Soricomopha, Primates, Artiodactyla, Cingulata and Pilosa). The production of genetic sequences has been useful as a species conservation tool (NOM-059); as supplement and update of species inventories, as well as evolutionary work and recognition of species (taxonomic identification). An aspect that is worth noting regards the issues faced by the mammal species included in the Convention on International Trade in Endangered Species of Wild Fauna and Flora CITES Appendices, where the generation of genetic information allows resource managers to use a molecular tool to curb the wildlife trafficking (www.barcodeofwildlife.org species).

It is clear that we are witnessing the loss of environments at a global level, either by climate change or an anthropic effect, which is leading to the fragmentation or modification of natural habitats and, therefore, to changes in the distribution of wildlife species. In addition to the slow taxa identification process (we only know 10 to 12 % of the total number of species). The decade of 2010 should be considered as the period of integral research in evolutionary biology as regards the study of the mammalian fauna, including comparative cytogenetic studies, ribosomal genes, microarrays and proteomics, gene mapping and genomes.

Table 2. Total number of records available for the most representative countries and orders in the genetic library. A) Cooperative Republic of Guyana; B) Mexico; C) Canada; D) Russia; E) Ecuador; F) Suriname; G) China (www.boldsystems.org).

Order	Total	A	B	C	D	E	F	G
Primates	22,356	4	16	66	652	12	--	137
Chiroptera	20,726	6,138	1,000	899	354	1,575	1,616	572
Rodentia	15,005	945	3,563	1,165	1,048	423	283	717
Carnivora	2,373	15	90	137	49	--	--	5
Soricomorpha	2,261	--	83	948	280	--	--	189
Artiodactyla	2,058	11	8	224	4	--	--	252
Cetacea	857	--	--	17	--	--	--	--
Didelphimorphia	633	113	93	8	--	37	33	--
Lagomorpha	525	--	205	8	90	2	--	15
Perissodactyla	522	--	--	--	--	1	--	4

Patricia Cortés-Calva

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Progress in the eradication of the feral cat (*Felis catus*) and recovery of the native fauna on Socorro Island, Revillagigedo Archipelago, Mexico

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Socorro Island, in the Revillagigedo Archipelago, has the highest number of endemisms of any Mexican island. It provides habitat for 117 vascular plants, 26 % of which are endemic to the island. Also endemic to the island are one reptile and eight terrestrial bird species. However, the local ecosystem has been heavily degraded by exotic mammals over the past 140 years. The feral sheep (*Ovis aries*) has contributed to a 30% loss in habitat based on the island's surface area. Another serious threat is the feral cat (*Felis catus*), which has severely impacted the island's bird communities and the endemic Socorro tree lizard (*Urosaurus auriculatus*). Together, feral sheep and cats are responsible for the extinction in the wild of the Socorro dove (*Zenaida graysoni*) and the Socorro Elf Owl (*Micrathene whitneyi graysoni*), and pose a serious threat for other vulnerable species, such as the Townsend's shearwater (*Puffinus auricularis*). The feral sheep was completely eradicated in 2012, which resulted in a rapid and remarkable recovery of the local vegetation cover. The eradication of the feral cat has been a complex issue to undertake due to the large size and topographical complexity of Socorro Island. In 2011 Grupo de Ecología y Conservacion de Islas, A. C. (GECI) started a feral cat control program, which scaled up into an eradication campaign. Here we report on the progress of the eradication campaign between 2011 and 2015, and provide a first assessment of the recovery of the native fauna. Beginning in 2011, camera traps were used to estimate cat abundance. Leg-hold and lethal traps were used to capture feral cats, some of them mounted with telemetry devices that alerted when traps were activated. Native vertebrates were monitored to confirm the positive effects derived from cat control efforts. By July 2015, 413 cats were dispatched using soft leg-hold and lethal traps, with a combined effort of 22,706 trap-nights. To date (mid-2016), cat abundance has decreased significantly, with cats being completely absent for several years in different areas of the island. The abundance of the endemic Socorro Island tree lizard and terrestrial birds has increased thanks to significant progress. Completing this important conservation action requires an increase in trapping efforts and the use of detection dogs, combined with night hunting. We estimate that the eradication of the feral cat will be completed by early 2017, after which the absence confirmation phase will begin.

Isla Socorro, Archipiélago de Revillagigedo, es la isla con el mayor nivel de endemismos en México. Es hábitat de 117 especies de plantas vasculares, 26 % de las cuales son endémicas. Alberga una especie de reptil y ocho especies de aves terrestres endémicas. Sin embargo, este ecosistema insular ha sido fuertemente degradado debido a la presencia de mamíferos exóticos por más de 140 años. El borrego feral (*Ovis aries*) causó la destrucción del hábitat en 30 % de la superficie de la isla. Otra seria amenaza es la presencia del gato feral (*Felis catus*), el cual ha tenido un severo impacto negativo por depredación sobre la avifauna nativa y la lagartija azul (*Urosaurus auriculatus*), endémica de Isla Socorro. Juntos, el gato y el borrego feral, son responsables de la extinción en el medio silvestre de la paloma de Socorro (*Zenaida graysoni*) y del tecolote de Socorro (*Micrathene whitneyi graysoni*), además de ser una seria amenaza para otras especies vulnerables, destacando la pardela de Revillagigedo (*Puffinus auricularis*). La erradicación del borrego feral se completó en 2012, lo que resultó en una rápida y notable recuperación de la cobertura vegetal. La erradicación del gato feral ha sido un reto mayor dado al gran tamaño y la complejidad topográfica de Isla Socorro. En 2011, el Grupo de Ecología y Conservación de Islas, A. C. (GECI) inició un programa de control de gato feral que poco tiempo después se convirtió en una campaña de erradicación. En este trabajo reportamos los avances de la erradicación entre los años 2011 y 2015, y ofrecemos una primera evaluación de la recuperación de la fauna nativa. Mediante el uso de cámaras trampa (a partir de 2011) se estimó la abundancia del gato feral. Para la captura de los gatos se emplearon trampas de cepo y letales, algunas equipadas con equipos de telemetría que alertan cuando éstas han sido activadas. Se realizaron monitoreos de vertebrados nativos a fin de confirmar los efectos positivos de los esfuerzos de control del gato feral. Hasta julio de 2015 se sacrificaron 413 gatos con trampas de cepo de cojinete y letales, con un esfuerzo acumulado de 22,706 trampas-noche. A la fecha (mediados de 2016), la abundancia de gatos ha disminuido aún más, y ya están completamente ausentes de varias zonas de la isla. La abundancia de la lagartija azul de Isla Socorro y las aves terrestres endémicas ha incrementado gracias a los avances en la erradicación del gato. A la fecha se ha logrado un avance significativo en la erradicación del gato feral. Para completar esta acción prioritaria de conservación, es necesario incrementar el esfuerzo de trampeo, así como el uso de perros de muestra combinado con cacería nocturna. Estimamos que la erradicación de gato feral se completará a principios de 2017, cuando iniciará la fase de confirmación de ausencia.

Key words: cat; conservation; eradication; *Felis catus;* Revillagigedo Archipelago; Socorro Island.

Introduction

The islands of Mexico are recognized worldwide for their high biodiversity, since these host a large number of endemic species (Aguirre-Muñoz *et al.* 2005; 2011; 2016). However, many islands in Mexico and around the world have experienced severe impacts resulting from human activities (Johnson and Stattersfield 1990; Chapuis *et al.* 1994; Algar *et al.* 2004; Bonnaud *et al.* 2011). Approximately 75 % of animal extinctions have occurred in islands, mainly because of introduced species (Ebenhard 1988; Diamond 1989; Groombridge 1992). Alien species are the main cause of biodiversity loss and ecological imbalance in many environments (Chapuis *et al.* 1994; Moro 1997; Bonnaud *et al.* 2011). In Mexico, cats were introduced into at least 34 islands, causing serious impacts on the native fauna and contributing to the disappearance of seabirds and the confirmed extinction of 17 species of birds and mammals in Mexican islands (Aguirre-Muñoz *et al.* 2011; 2016). In Guadalupe Island, for example, the feral cat has been responsible for the extinction of endemic species such as the birds Guadalupe Bewick's wren (*Thyromanes bewickii brevicauda*) and the Guadalupe towhee (*Pipilo maculatus consobrinus*), in addition to posing a risk for seabird populations, including the likely extinction of the Guadalupe storm petrel (Hernández-Montoya *et al.* 2014).

In the case of Socorro Island, the feral sheep (*Ovis aries*), the feral cat (*Felis catus*) and the domestic mouse (*Mus musculus*) have caused significant negative impacts on the ecosystem. The feral sheep was responsible for soil erosion, loss of vegetation cover and habitat modification (Levin and Moran 1989; Alvarez-Cárdenas *et al.* 1994; León de la Luz *et al.* 1994; Maya-Delgado *et al.* 1994; Brattstrom 2015), which led to negative impacts on the native fauna (Martínez-Gomez *et al.* 2001). For its part, the feral cat, introduced into the island in the 1950s, poses a serious threat for the local vertebrate populations. Predation by cats threatens the persistence of native species, particularly those of small population size, such as the Socorro tree lizard (*Urosaurus auriculatus*; Arnaud *et al.* 1993; 1994). Likewise, feral cats contributed to the extinction in the wild of the Socorro dove (*Zenaida graysoni*) and the Socorro elf owl (*Micrathene whitneyi graysoni*), and has also led to other species being listed as endangered of extinction, as is the case of the Socorro mockingbird (*Mimus graysoni*) and the Townsend´s shearwater (*Puffinus auricularis*; Martinez-Gomez and Jacobsen 2004).

Achieving the recovery of both the habitat and native species requires the eradication of the introduced species (Veitch and Clout 2002; Aguirre-Muñoz *et al.* 2005; Veitch *et al.* 2011;Jones *et al.* 2016). Given the threats that Socorro Island currently faces, from 2009 to 2012 the Mexican environmental organization named Grupo de Ecología y Conservación de Islas, A. C. (GECI) undertook the eradication of the feral sheep that has led to a remarkable homeostatic environmental recovery (Ortiz-Alcaraz *et al.* 2016a; 2016b). The eradication of the feral cat represented another serious challenge, since Socorro is a large and complex island, and little baseline information was available on the distribution and abundance of this species (Arnaud *et al.* 1994). Fortunately, technologies have been developed in islands in Mexico and worldwide for the eradication of feline predators (Bester *et al.*2002; Wood *et al.* 2002; Algar *et al.* 2010; Aguirre-Muñoz *et al.* 2011; Luna-Mendoza *et al.* 2011; Parkes *et al.* 2014). For the successful implementation of an eradication campaign of this type, is essential to determine the ecology of the species, assess the impact of the applied methods on the native fauna, and to develop an executive eradication plan (Veitch 1989; Arnaud *et al.* 1994; Donlan *et al.* 2003; Dowding *et al.* 2009). Given the imminent risk that predation by cats posses to the island's endemic species, there was an urgent need to execute a control program that would provide information about the biology of this predator. Thus, an intensive monitoring program of feral cats in Socorro Island was launched in 2000, aimed at achieving its eradication. This work describes the methods used, the progress achieved between 2011 and 2015, and the preliminary results of the recovery of native fauna after the implementation of erradication efforts.

Materials and Methods

Study area. Socorro Island is a federal territory that belongs to the Revillagigedo Archipelago. It is located 460 km south of Cabo San Lucas, Baja California Sur, and 694 km west of Manzanillo, Colima (18.7833° N, -110.9666° W, Figure 1). It comprises an area of 132 km^2 with a maximum altitude of 1,050 m. The island is home to 117 species of vascular plants, 30 of which are endemic (León de la Luz *et al.* 1994). The fauna of Socorro Island includes 103 species of terrestrial birds, eight species of which are endemic, seabirds and one endemic reptile, the Socorro Island tree lizard, endemic to the island. In addition, Socorro Island is the only nesting site of the Townsend´s shearwater, a seabird endemic to the archipelago. The island is permanently inhabited by 50 soldiers of Mexico's Secretariat of the Navy (SEMAR, for its acronym in Spanish), which has a Naval Sector in the southeastern end of the island (CONANP 2004).

Feral cat monitoring and control. The relative abundance of cats was estimated using camera traps. During April-May and November of 2011 to 2015 (two annual monitoring events, one for each season), eight transects with camera traps were set (Bushnell Trophy cam HD Agressor). Each transect ran across 3 km and included a total of 10 camera traps with a 300-m separation between them (Figure 1A). Cameras were installed at a height of approximately 50 cm from the ground, slightly tilted downwards, and were set to take a sequence of five photographs per minute when motion was detected. A commercial cat bait made of seafood was used (Shellfish, Tomahawk Live Trap). Cameras remained active for three consecutive nights, representing an effort of 240 trap-nights in each biannual monitoring. The relative abundance index was calculated as the total number of visits (animals individually identified according to distinctive traits through photographs), divided by the total number of trap-nights.

According to Arnaud *et al.* (1994), cats are located mainly in the eastern area of the island; therefore, it was decided to concentrate the initial catch effort in that area. The control method consisted mainly in catching cats using leg-hold traps (Oneida Victor Soft Catch #1 ½) and lethal traps (Conibear Bodygrip Traps 10"), according to the experience in other islands in Mexico and worldwide (Rauzon 1985; Twyford *et al.* 2000; Phillips *et al.* 2005; Rodríguez *et al.* 2006; Rauzon *et al.* 2008; Luna-Mendoza *et al.* 2011). Leg-hold traps including pads were placed to fulfill good humanitarian practices (NOM-033-ZOO-1995) in 220 sites (Figure 1B) over the duration of the expedition (21 to 51 days), and baited with a commercial cat bait made of seafood, tuna or fried sardine (Brothers 1982). Traps were reviewed daily from 7:00 to 10:00 h. Lethal and leg-hold traps located in hard-to-access sites were equipped with telemetry systems (ATS, mammal trap monitor Series M4000) to determine whether they had been activated from a distance (Will *et al.* 2010). Once cats were captured, these were euthanized by intramuscular injection of an anesthetic (Zoletil 50, Laboratories VIRBAC Mexico) and a lethal intracardiac injection (pentobarbitol), also following humanitarian euthanasia best practice guidelines (NOM-033-ZOO-1995). As a secondary method, night hunting was conducted using 0.222 caliber and 0.22 rifles with telescopic sights and lamps (Kohree 80,000 lux). The capture success was estimated with the formula e = (cats captured/trap-nights) x 100.

Monitoring of native fauna. Since cats predate mainly on domestic mice, tree lizards and terrestrial birds (Arnaud *et al.* 1993; 1994), it was necessary to carry out a monitoring of the native species to determine and document any changes resulting from the control of the feral cat in Socorro Island. The Socorro Island tree lizard was monitored during April-May and October (two seasons per year) from 2012 to 2015. Twenty four transects were set (Aguirre-León 2011) in three different types of habitat (eight transects per habitat type): forest, deciduous scrubland and eroded areas or areas impacted by sheep (devoid of vegetation, León de la Luz *et al.* 1994), each measuring 6 m wide by 100 m long (Figure 1C). Transects were visited during three consecutive days in each biannual monitoring, between 10:00 and 12:00 h. Density was estimated using the following formula: D = ($n/2wL$).

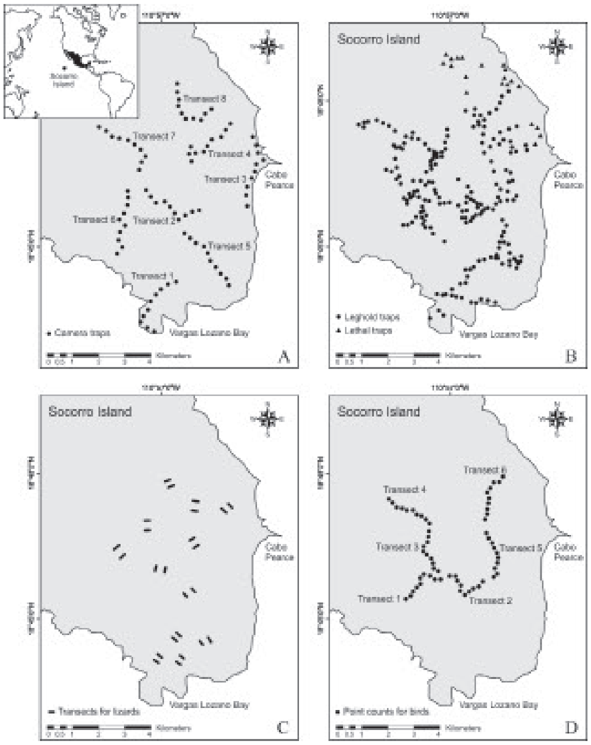

Figure 1. Location of A) transects of odor stations for monitoring feral cats through camera traps. B) Leg-hold trap (circles) and lethal traps (triangles) for the control of feral cats. C) transects for monitoring the Socorro Island tree lizard. D) Count-point transects for monitoring terrestrial birds.

Where n is the number of individuals counted, L is total transect length, and w is the width of the transect (Gallina and López-González 2011). A one-way repeated measures analysis of variance (rANOVA) was conducted to determine the effect of the season and habitat type on tree lizard density. The statistical software R version 3.2.2 was used.

Terrestrial birds were monitored using the point-count technique (González-García 2011). Six transects were established in the island during April-May and October (two seasons per year) from 2012 to 2015 (Figure 1D). The monitoring was carried out from 6:30 to 9:30 h and was repeated on three consecutive days in each biannual season. At each site, all birds observed within a radius of 25 m during five minutes were counted. Subsequently, the observer moved to the next counting point located 250 m away, with a five-minute break before starting the next count. The statistical test rANOVA was run to determine the effect of season and habitat type on the total number of birds, plus Student *t*-tests for paired samples with a Bonferroni adjustment, to compare sightings during the different seasons.

Results

Feral cat monitoring and control. Camera trapping was used to determine the relative abundance of cats in the various zones of the eastern part of the island, as well as to guide capture efforts. In 2012, cats were found in all the sites studied; their abundance was higher toward the southeast (close to the Naval Sector), and lower in the northern zone and in the areas with the highest altitude (1,050 masl) in the central part of the island. As the cat control program progressed, the abundance of cats decreased drastically. By May 2015, cats were located only in transects recorded in the southernmost areas of the island (Figure 2). It was also noted that a lower number of cats in the entire island was observed as the monitoring seasons progressed. The success of cat capture during the trapping activities fluctuated throughout the year. However, a clear trend toward a smaller population was noted on a multi-year timescale (Figure 3). In general terms, the success of capture is greater in the dry season, and decreases during the rainy season (Table 1). Eight cats were dispatched by night hunting, to recover GPS collars; these specimens were not considered in the table of capture success.

Monitoring of native fauna. The results of tree lizard monitoring reveal that the population is increasing, considering both the dry and rainy seasons (Figure 4). Lizard density fluctuated significantly between seasons since the trapping of cats started in Socorro Island, $F_{(6.12)} = 4.4$, $p = 0.014$.

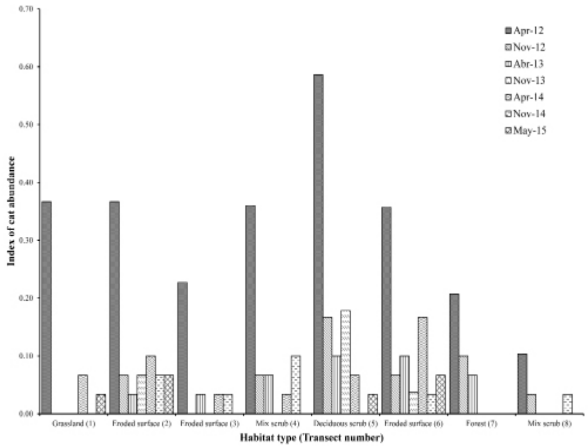

Figure 2. Relative abundance index of feral cats from 2012 to 2015 by vegetation type.

The number of birds sighted from 2012 to 2015 also showed significant differences between seasons, $F_{(5.96)} = 5.36$, $P = 2.2 \times 10^{-4}$. Although a population fluctuation is evident over the years of the study, there is an increase in the dry seasons of 2014 and 2015 (Table 2, Figure 5). Significant differences were found between November 2012 (study start-up and time point next to the eradication program start-up) and the rest of the monitoring monitoring times (except November 2014). No significant differences were found between dry seasons during the years 2013 to 2015. The most abundant species was the Socorro warbler (*Setophaga pitiayumi graysoni*), followed by the Socorro wren (*Troglodytes sissonii*), and the towhee (*Pipilo maculatus socorrensis*), all of them endemic to the island (Figure 5).

Discussion

A study to determine the home range of cats conducted in 2013 (Ortiz-Alcaraz, unpublished data), where necklaces fitted with GPS/VHF (Sirtrack Mod. G2C 128aWGPS 170 to 230 mm Necklace) were placed to six animals, revealed a mean home range of 2.19 km^2 for males and 1.18 km^2 for females. Based on this information and the experience in other Mexican islands (Luna-Mendoza *et al.* 2011), it was determined that traps should be separated by 300-500 meters to ensure that animals encounter at least one trap during their foraging movements.

Monitoring feral cat has served to adjust the trap-placement effort in the eastern part of the island, where they are most abundant (Arnaud *et al.* 1994). The trapping effort should continue in order to catch the cats moving from one area to another. The capture of cats increases during the dry season (December to May) and decreases in the rainy season (June to November). These findings are not related to the abundance of cats, but are a sampling artifact, since moist land interferes with the installation of leg-hold traps, dry substrate to cover them is unavailable while rain compacts and hardens the substrate covering the traps impeding their activation. At the same time, another key factor that affects trapping in the rainy season is the higher abundance of land crabs (*Gecarcinus planatus*), which either consume the baits placed in traps or activate traps when attempting to reach the bait. Crabs are not caught in traps because they reach the bait from the back of the trap, but traps are nonetheless activated due to the crab's foraging activity. The combination of lethal traps and telemetry devices is essential during trapping in the most remote areas of the island. In this way, traps do not have to be checked daily but every five to seven days to replenish any bait lost to insects (mainly ants) and crabs (Parkes *et al.* 2012).

Table 1. Trap-nights, cats killed and capture success of feral cats in Socorro Island in the dry and rainy seasons from 2011 to 2015.

Year	Season	Trap-nights	Cats killed	Success of capture
2011	Rainy	1,308	82	6.27
2012	Dry	388	33	8.51
	Rainy	1,632	31	1.90
2013	Dry	2,097	78	3.72
	Rainy	1,141	22	1.93
2014	Dry	2,667	69	2.59
	Rainy	6,665	48	0.72
2015	Dry	5,080	43	0.85
	Rainy	1,728	7	0.41
	TOTAL	22,706	413	

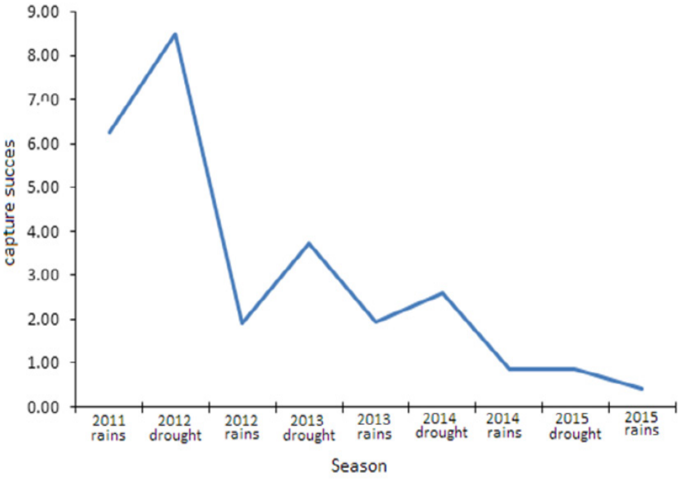

Figure 3. Reduction in the capture success (%) of feral cats in the rainy and dry seasons from 2012 to 2015.

The Socorro Island tree lizard was found at higher densities in the deciduous scrubland, being less abundant in forests at higher altitudes. The results of this study show that the density of lizards in eroded surfaces was as high as 43 individuals/ha after cat was controlled, while Gallina-Tessaro *et al.* 1994 reported not having observed lizards in these areas. This may be due to a gradual recovery of the vegetation

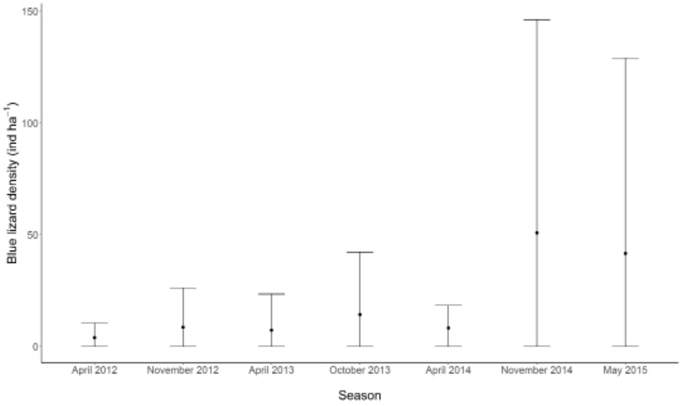

Figure 4. Mean density of the Socorro Island tree lizard (*Urosaurus auriculatus*), with confidence intervals, for the dry and rainy seasons from 2011 to 2015 in Socorro Island.

Table 2. Sample size (N) of each season, average and standard deviation (SD) of the total number of birds for each season and its corresponding confidence interval (CI) for the average number of birds along 6 transects, with a confidence level of 95 %.

Year	Season	N	Mean	SD	CI
2012	Rainy	18	19.44	6.16	16.38 – 22.51
2013	Dry	18	38.56	14.16	31.51 – 45.60
	Rainy	18	28.83	9.22	24.25 – 33.42
2014	Dry	18	52.00	19.87	42.12 – 61.88
	Rainy	18	24.11	7.81	20.23 – 28.00
2015	Dry	18	50.89	31.01	35.47 – 66.31

resulting from the recent eradication of sheep (Ortiz-Alcaraz *et al.* 2016a; 2016b) and to the sustained trapping of cats in these areas. Lizard density was slightly higher during the rainy season, likely due to a higher food availability. As the cat control program in the eastern area of the island has progressed, the predation pressure of cats on the lizard population has decreased. Lizards are a major component of the cat's diet (50 % of fecal samples of cats analyzed contained lizard remains; Arnaud *et al.*1993).

The whighest number of birds was observed was the forest (*Ficus* - *Guettarda* - *Ilex*) vegetation type, especially in the highest parts of the island, where the recovery of vegetation resulting from the absence of grazing after sheep were eliminated has led to a greater availability of food and shelter against predators (Rodríguez-Estrella *et al.* 1994). Special efforts have been made to control cats in the forest, aiming to protect the native bird species such as the Townsend's shearwater (Ratcliffe *et al.* 2009). In 2015, a lower number of birds were watched relative to 2014 in eroded areas, *Ficus* (amate) forests and mixed shrubland. It is considered that the reduction is due to the visual interference of vegetation, as these areas had been previously eroded and subsequently colonized by shrub speceies such as *Hyptis pectinata* (up to 2.5 m height), *Dodonaea viscose* and the common fern (*Pteridium caudatum*). Additionally, to the above, cats are still present in these habitats, likely because of the considerable coverage provided by this type of vegetation. The eradication of feral cat and the monitoring of the native fauna should continue, in order to confirm recovery and to increase of the population size of the native fauna.

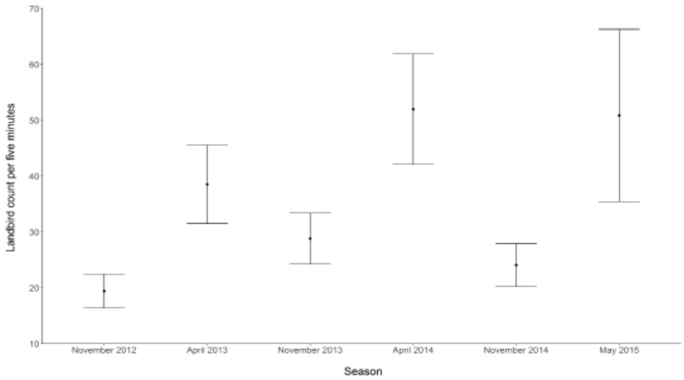

Figure 5. Average number of terrestrial birds with confidence intervals sighted during the dry and rainy seasons from 2012 to 2015 on Socorro Island.

The plans developed by Veitch (1989), Arnaud *et al.* (1993) and Parkes *et al.* (2012) agree in that feral cat can be eradicated using traditional techniques: trapping and night hunting. However, the experience in the island has highlighted the importance of using detection dogs to locate the remaining cats, either during the day, in their dens (providing an opportunity to set traps), or at night where cats may be killed by night hunting (Tortora 1982; Veitch 2001), as well as for the statistical confirmation of cat absence during the final stage of an eradication campaign (Ramsey *et al.* 2011).

As the eradication of feral cat in Socorro Island progresses, the populations of native vertebrates are recovering, as has happened in other islands (Rodriguez-Moreno *et al.* 2007; Aguirre-Muñoz *et al.* 2011). Once the absence of the cat in the island is confirmed statistically, the essential conditions for the successful reintroduction of the Socorro dove, —a species currently extinct in the wild and preserved in captivity only —will be established (Yanga *et al.* 2011).

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Literature cited

Aguirre-León, G. 2011. Métodos de estimación, captura y contención de anfibios y reptiles. Pp. 48-65 in Manual de Técnicas para el estudio de la Fauna (Gallina, S., and C. López, eds.). Volumen I. Universidad Autónoma de Querétaro-Instituto Nacional de Ecología, A.C. Querétaro, Mexico.

Aguirre-Muñoz, A., A. Samaniego-Herrera, C. García-Gutiérrez, L. Luna-Mendoza, M. Rodríguez-Malagón, and F. Casillas-Figueroa. 2005. El control y la erradicación de fauna introducida como instrumento de restauración ambiental: historia, retos y avances en México. Pp. 215-230, in Temas sobre restauración ecológica (Sánchez, Ó., E. Peters, R. Márquez-Huitzil, E. Vega, G. Portales, M. Valdez, and D. Azuara, eds.). Instituto Nacional de Ecología. Ciudad de México, Mexico.

Aguirre-Muñoz, A., A. Samaniego-Herrera, L. Luna-Mendoza, A. Ortiz-Alcaraz, M. Rodríguez-Malagón, F. Méndez-Sánchez, M. Félix-Lizárraga, J. C. Hernández-Montoya, R. González-Gómez, F. Torres-García, J. M. Barredo-Barberena, and M. Latofski-Robles. 2011. Island restoration in Mexico: ecological outcomes after systematic eradications of invasive mammals. Pp. 250-258, in Island Invasives: Eradication and Management (Veitch, C. R., M. N. Clout, and D. R. Towns, eds.). Proceedings of the International Conference on Island Invasive. Occasional Paper of the IUCN Species Survival Commission No. 42. Gland, Suiza and Auckland, New Zealand.

Aguirre-Muñoz, A., A. Samaniego-Herrera, L. Luna-Mendoza, A. Ortiz-Alcaraz, F. Méndez-Sánchez, and J. Hernández-Montoya. 2016. La restauración ambiental exitosa de las islas de México: una reflexión sobre los avances a la fecha y los retos por venir. Pp. 487-514, in Experiencias mexicanas en la restauración de los ecosistemas (Ceccon E., and C. Martínez-Garza, eds.). CRIM-UNAM y CONABIO. Ciudad de México, Mexico.

Algar, D., C. J. Angus, R. I. Brazell, C. Gilbert, and D. J. Tonkin. 2004. Feral cats in paradise: Focus on Cocos. Atoll Research Bulletin 505:1-12.

Algar, D., G. J. Angus, R. I. Brazell, C. Gilbert, and G. B. Withnell. 2010. Eradication of feral cats on Faure Island, Western Australia. Journal of the Royal Society of Western Australia 93:133-140.

Álvarez-Cárdenas, S., A. Castellanos-Vera, P. Galina-Tessaro, and G. Arnaud. 1994. Aspectos de la población y el hábitat del borrego doméstico (*Ovis aries*). Pp. 301–317, in La Isla Socorro, Reserva de la Biosfera Archipiélago de Revillagigedo, México (Ortega-Rubio, A., and A. Castellanos-Vera, eds.). Centro de Investigaciones Biológicas del Noroeste, S. C. La Paz, Mexico.

Arnaud, G., A. Rodríguez, A. Ortega-Rubio, and C. S. Álvarez. 1993. Predation by cats on the unique endemic lizard of Socorro Island (*Urosaurus auriculatus*), Revillagigedo, México. Ohio Journal of Science 93:101-104.

Arnaud, G., A. Rodríguez, and S. Álvarez. 1994. El gato doméstico (*Felis catus*), implicaciones de su presencia y alternativas para su erradicación. Pp. 341-359, in La Isla Socorro, Reserva de la Biosfera Archipiélago de Revillagigedo, México (Ortega-Rubio, A., and A. Castellanos-Vera, eds.). Centro de Investigaciones Biológicas del Noroeste, S. C. La Paz, Mexico.

Bester, M. N., J. P. Bloomer, R. J. Van Aarde, B. H. Erasmus, P. J. Van Rensburg, J. D. Skinner, P. G. Howell, and T. W. Naude. 2002. A review of the successful eradication of feral cats from sub-Antarctic Marion Island, Southern Indian Ocean. South African Journal of Wildlife Research 32:65-73.

Bonnaud, E., F. Medina, E. Vidal, M. Nogales, B. Tershy, E. Zavaleta, C. J. Donlan, B. Keitt, M. Le Corre, and S. V. Horwath. 2011. The diet of feral cats on islands: a review and a call for more studies. Biological Invasions 13:581-603.

Brattstrom, B. H. 2015. Food Webs and Feeding Habits on the Revillagigedo Islands, Mexico. Pacific Science 69:181-195.

Brothers, N. P. 1982. Feral cat control on Tasman Island. Australian Ranger Bulletin 2:9.

Comisión Nacional de Áreas Naturales Protegidas (CONANP). 2004. Programa de conservación y manejo Reserva de la Biosfera Archipiélago de Revillagigedo. CONANP-SEMARNAT. Ciudad de México, Mexico.

Chapuis, J. L., P. Boussès, and G. Barnaud. 1994. Alien mammals, impact and management in the French subantarctic islands. Biological Conservation 67:97-104.

Diamond, J. M. 1989. Overview of recent extinctions. Pp 37-41, in Conservation for the twenty-first century (Western, D., and M.C. Pearl, eds.). Oxford University Press. New York, USA.

Donlan, C. J., B. R. Tershy, K. J. Campbell, and F. Cruz. 2003. Research for requiems: the need for more collaborative action in eradication of invasive species. Conservation Biology 17:1-2.

Dowding, J. E., E. C. Murphy, K. Springer, A. J. Peacock, and C. J. Krebs. 2009. Cats, rabbits, myxoma virus, and vegetation on Macquarie Island: a comment on Bergstrom *et al*. (2009). Journal of Ecology 46:1129-1132.

Ebenhard, T. 1988. Introduced birds and mammals and their ecological effects. Swedish Wildlife Research 13:1-107.

Galina-Tessaro, P., S. Alvarez-Cárdenas, and A. Ortega. 1994. Aspectos ecológicos de la Herpetofauna. Pp. 185-197 in La Isla Socorro, Reserva de la Biósfera Archipiélago de Revillagigedo, México (Ortega-Rubio, A., and A. Castellanos-Vera eds.). Centro de Investigaciones Biológicas del Noroeste, S. C. La Paz, México.

Gallina, S., and C. López-González (eds). 2011. Manual de técnicas para el estudio de la fauna. Volumen I. Universidad Autónoma de Querétaro-Instituto de Ecología A. C. Querétaro, Mexico.

González-García, F. 2011. Métodos para contar aves terrestres. Pp. 128-147 in Manual de técnicas para el estudio de la fauna Volumen I (Gallina, S., and C. López-González eds.). Universidad Autónoma de Querétaro-Instituto Nacional de Ecología, A. C. Querétaro, Mexico.

Groombridge, B. E. 1992. Global Diversity - Status of the Earth's Living Resources. Compiled by the World Conservation Monitoring Center. Chapman & Hall. London, United Kingdom.

Hernández-Montoya, J. C., L. Luna-Mendoza, A. Aguirre-Muñoz, F. Méndez-Sánchez, M. Félix-Lizárraga, and J. M. Barredo-Barberena. 2014. Laysan Albatross on Guadalupe Island, México: current status and conservation actions. Monographs of the Western North American Naturalist 7:543-554.

Johnson, T. H., and A. J. Stattersfield. 1990. A Global Review of Island Endemic Birds. The Ibis 132:167-180.

Jones, H. P., N. D. Holmes, S. H. M. Butchart, B. R. Tershy, P. J. Kappes, I. Corkery, A. Aguirre-Muñoz, D. P. Armstrong, E. Bonnaud, A. A. Burbidge, K. Campbell, F. Courchamp, P. E. Cowan, R. J. Cuthbert, S. Ebbert, P. Genovesi, G. R. Howald, B. S. Keitt, S. W. Kress, C. M. Miskelly, S. Oppel, S. Poncet, M. J. Rauzon, G. Rocamora, J. C. Russell, A. Samaniego-Herrera, P. J. Seddon, D. R. Spatz, D. R. Towns, and D. A. Croll. 2016. Invasive mammal eradication on islands results in substantial conservation gains. Proceedings of the National Academy of Sciences 113:4033-4038.

León de la Luz, J. L., A. Breceda, R. Coria-Benet, and J. Cancino-Hernández. 1994. Asociaciones vegetales. Pp. 115–141, in La Isla Socorro, Reserva de la Biosfera Archipiélago de Revillagigedo, México (Ortega-Rubio, A., and A. Castellanos-Vera, eds.). Centro de Investigaciones Biológicas del Noroeste, S. C. La Paz, Mexico.

Levin, J. A., and R. Moran. 1989. The vascular flora of Isla Socorro, México. San Diego Society of Natural History University of Michigan. San Diego, U. S. A.

Luna-Mendoza, L., J. M. Barredo-Barberena, J. C. Hernández-Montoya, A. Aguirre-Muñoz, F. Méndez-Sánchez, A. Ortiz-Alcaraz, and M. Félix-Lizárraga. 2011. Planning for the eradication of feral cats on Guadalupe Island, México: home range, diet, and bait acceptance. Pp. 192-197 in Island Invasives: Eradication and Management (Veitch, C. R., M. N. Clout, and D. R. Towns, eds.). Proceedings of the International Conference on Island Invasives. Occasional Paper of the IUCN Species Survival Commission No. 42. Gland, Switzerland and Auckland, New Zealand.

Martínez-Gómez, J. E., A. Flores-Palacios, and R. L. Curry. 2001. Habitat requirements of the Socorro Mockingbird *Mimodes graysoni*. Ibis 143:456-467.

Martínez-Gómez, J. E., and J. Jacobsen. 2004. The Conservation Status of Townsend's Shearwater *Puffinus auricularis*. Biological Conservation 116:35–47.

Maya-Delgado, Y., F. Salinas-Zavala, and E. Troyo-Diéguez. 1994. Estado actual del suelo y propuestas para su conservación. Pp. 63–75 in La Isla Socorro, Reserva de la Biosfera Archipiélago de Revillagigedo, México (Ortega-Rubio, A., and A. Castellanos-Vera, eds.). Centro de Investigaciones Biológicas del Noroeste, S. C. La Paz, Mexico.

Moro, D. 1997. Removal of a feral cat from Serrurier Island. The Western Australian Naturalist 21:153-156.

Ortiz-Alcaraz, A., A. Aguirre-Muñoz, F. Méndez-Sánchez, and A. Ortega-Rubio. 2016a. Feral sheep eradication at Socorro Island, Mexico: A mandatory step to ensure ecological restoration. Interciencia 41:184-189.

Ortiz-Alcaraz, A., Y. Maya-Delgado, P. Cortés-Calva, A. Aguirre-Muñoz, E. Rojas-Mayoral, M. Cordoba-Matson, and A. Ortega-Rubio. 2016b. Recovery of Vegetation Cover and Soil after the Removal of Sheep in Socorro Island, Mexico. Forests 7:91.

Parkes, J., P. Fisher, and S. Robinson. 2012. Eradication of feral cats on large Mexican Islands: a discussion of options and feasibility. Lincoln, New Zealand: Invasive Species International, Landcare Research New Zealand.

Parkes, J., P. Fisher, S. Robinson, and A. Aguirre-Muñoz. 2014. Eradication of feral cats from large islands: an assessment of the effort required for success. New Zealand Journal of Ecology 38:307-314.

Phillips, R. B., B. D. Cooke, K. Campbell, V. Carrion, C. Marquez, and H. L. Snell. 2005. Eradicating feral cats to protect Galápagos land iguanas: methods and strategies. Pacific Conservation Biology 11:57-66.

Ramsey, D. S. L., J. P. Parkes, D. Will, C. C. Hanson, and K. J. Campbell. 2011. Quantifying the success of feral cat eradication, San Nicolas Island, California. New Zealand Journal of Ecology 35:163-173.

Ratcliffe, N., M. Bell, T. Pelembe, D. Boyle, R. Benjamin, R. White, B. Godley, J. Stevenson, and S. Sanders. 2009. The eradication of feral cats from Ascension Island and its subsequent recolonization by seabirds. Oryx 44:20-29.

Rauzon, M. J. 1985. Feral cats on Jarvis Island: their effects and their eradication. Atoll Research Bulletin 282:1-30.

Rauzon, M. J., W. T. Everett, D. Boyle, L. Bell, and J. Gilardi. 2008. Eradication of feral cats at Wake Atoll. Atoll Research Bulletin 560:1-21.

Rodríguez-Estrella, R., L. Rivera, and E. Mata. 1994. Avifauna terrestre. Pp. 199–224 in La Isla Socorro, Reserva de la Biosfera Archipiélago de Revillagigedo, México (Ortega-Rubio, A., and A. Castellanos-Vera, eds.). Centro de Investigaciones Biológicas del Noroeste, S. C. La Paz, Mexico.

Rodríguez, C., R. Torres, and H. Drummond. 2006. Eradicating introduced mammals from a forested tropical island. Biological Conservation 130:98-105.

Rodríguez-Moreno, A., G. Arnaud, and B. Tershy. 2007. Impacto de la erradicación del gato (*Felis catus*), en dos roedores endémicos de la isla Coronados, Golfo de California, México. Acta Zoológica Mexicana (n. s.) 23:1-13.

Tortora, D. F. 1982. Understanding electronic dog-training.1. Canine Practice 9:17-22.

Twyford, K. L., P. G. Humphrey, R. P. Nunn, and L. Willoughby. 2000. Eradication of feral cats (*Felis catus*) from Gabo Island, south-east Victoria. Ecological Management and Restoration 1:42-49.

Veitch, C. R. 1989. The eradication of cats and sheep from Socorro Island: A report to the Socorro Island project. Northern region technical report series. Department of Ccnservation. Auckland, Nueva Zelanda.

Veitch, C. R. 2001. The eradication of feral cats (*Felis catus*) from Little Barrier Island, New Zealand. New Zealand Journal of Zoology 28:1-12.

Veitch, C. R., and M. N. Clout (eds.). 2002. Turning the Tide: The Eradication of Invasive Species. Proceedings of the International Conference on Eradication of Island Invasives. Occasional Paper of the IUCN Species Survival Commission No. 27. Gland, Switzerland.

Veitch, C. R., M. N. Clout, and D. R. Towns (eds.). 2011. Island Invasives: Eradication and Management. Proceedings of the International Conference on Island Invasives. Gland, Switzerland and Auckland, New Zealand.

Will, D., C. C. Hanson, K. J. Campbell, D. K. Garcelon, and B. S. Keitt. 2010. A trap monitoring system to enhance efficiency of feral cat eradication and minimize adverse effects on non-target endemic species on San Nicolas Island. Proceedings of the Vertebrate Pest Conference 24:79-85.

Wood, B., B. R. Tershy, M. A. Hermosillo, C. J. Donlan, J. A. Sánchez, B. S. Keitt, D. A. Croll, G. R. Howard, and N. Biavaschi. 2002. Removing cats from islands in north-west Mexico. Pp. 374-380 in Turning the tide: the eradication of invasive species (Veitch, C. R., and M. N. Clout, eds.). IUCN SSC Invasive Species Specialist Group. Gland, Switzerland an Cambridge, United Kingdom.

Yanga, S., J. Martínez-Gómez, R. Sehgal, P. Escalante, F. Camacho, and D. Bell. 2011. A preliminary survey for avian pathogens in Columbiform birds on Socorro Island, Mexico. Pacific Conservation Biology 17:11-20.

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Ecology and conservation of ocelot (*Leopardus pardalis*) in Northern Quintana Roo, Mexico

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Ocelots are at risk of extinction due to anthropogenic pressures. Therefore, it is essential to generate information about this species in zones with climatic and anthropogenic pressures in order to determine appropriate measures for their conservation. Our goals were to determine population density, relative abundance, activity patterns and minimum observed home ranges of ocelots in northern Quintana Roo, Mexico. During 2008, we conducted systematic sampling for 60 days using camera-traps in Northern Quintana Roo, Mexico. The camera-trap grid covered an area of 81 km^2 and included El Eden Ecological Reserve. We placed 27 camera-trap stations: 18 with a single camera and 9 with two. Camera-trap stations were spaced approximately 1 kilometer apart. Our total sampling effort was 2160 trap-days. We registered 12 individual ocelots: five males, six females, and one of undetermined sex. The density estimated using CAPTURE program was 14 ind/100 km^2, while the density estimated for each sex separately was 7 ind/100 km^2. We estimated a relative abundance index of 1.85 ± 0.27 in tropical forest, 1.11 ± 0.22 in secondary vegetation and 0.185 ± 0.09 in savannah. The ocelot was more active at night. The minimum observed home range of male ocelots was larger than that of females, 4.63 km^2 and 1.80 km^2 respectively. We presented some ecological data of ocelot in El Eden Ecological Reserve and its area of influence. These results constitute an important baseline to make a comparison in areas adjacent that have strong climatic and anthropic pressures. Finally, the area is one of the most important for the conservation of ocelot in México.

El ocelote está en riesgo de extinción debido a factores antropogénicos. Por lo tanto, generar información sobre esta especie en zonas con impactos climáticos y antrópicos se convierte en esencial para determinar medidas adecuadas para su conservación. Nuestros objetivos fueron determinar la densidad de población, abundancia relativa, los patrones de actividad y áreas mínimas de acción del ocelote en el norte de Quintana Roo, México. Durante el 2008 se realizó un muestreo sistemático de 60 días mediante foto-trampeo en el norte de Quintana Roo. El diseño se implementó para muestrear un área de 81 km^2, que incluye a la Reserva Ecológica El Edén. Se colocaron 27 estaciones de cámaras trampa, 18 fueron sencillas y 9 dobles, cada estación de foto-trampeo tuvo una separación aproximada de 1 kilómetro. En total tuvimos un esfuerzo de muestreo de 2160 días/trampa. Se registraron 12 ocelotes, cinco machos, seis hembras y un individuo sin determinar el sexo. La densidad estimada de ocelotes usando el programa "CAPTURE" fue de 14 ind/100 km^2, mientras que la densidad estimada para machos y hembras fue de 7 ind/100 km^2. El índice de abundancia relativa fue de: 1.85 ± 0.27 para selva mediana, 1.11 ± 0.22 para vegetación secundaria y 0.185 ± 0.09 para sabana. El ocelote presentó su mayor actividad por la noche y el área de acción de los machos fue mayor al de las hembras, 4.63 km^2 y 1.80 km^2, respectivamente. Se obtuvieron algunos estimadores sobre la ecología del ocelote en la Reserva Ecológica El Edén y su área de influencia. Estos parámetros constituyen una base fundamental para hacer una comparación en áreas adyacentes sujetas a fuertes presiones climáticas y antrópicas. Finalmente, esta zona es una de las de mayor importancia en México para la conservación del ocelote.

Keywords: Activity patterns; camera traps; conservation area; density; endangered species; home range; relative abundance; Yucatan Peninsula

Introducción

El ocelote (*Leopardus pardalis*) es una de las cinco especies de felinos Neotropicales que se distribuyen en México (Aranda 2005). En México, su distribución abarca los estados de Sonora, Sinaloa, Nuevo León, Tamaulipas, Zacatecas, San Luis Potosí, Aguascalientes, Guanajuato, hacia el centro Hidalgo, Puebla, Morelos y Oaxaca y hacia el sur en Chiapas, Quintana Roo hasta Yucatán (Aranda *et al.* 2014; Bárcenas y Medellín 2010; Galindo-Aguilar *et al.* 2016; García-Bastida *et al.* 2016; Hernández-Flores *et al.* 2013; Iglesias *et al.* 2008; Martínez-Calderas *et al.* 2011; Valdez-Jiménez *et al.* 2013). Este felino al igual que otras especies de vertebrados terrestres, tiene problemas de conservación (*e. g.*, pérdida y fragmentación de hábitat, caza ilegal por depredación de aves de corral y el comercio ilegal de pieles), que en conjunto han provocado una reducción paulatina de su área de distribución en México y en los otros países donde se distribuye, originando un declive poblacional y en otros casos la desaparición local (Aranda 2005; Di Bitetti *et al.* 2008; Sunquist y Sunquist 2002). Es por ello, que este felino en México se encuentra en la categoría de especie en peligro de extinción y su caza está prohibida (NOM-059, SEMARNAT 2010), mientras que la Unión Internacional para la Conservación de la Naturaleza y los Recursos Naturales (IUCN, por sus siglas en inglés) la clasifica como especie de preocupación menor (IUCN 2015) y su comercialización se encuentra regulada por CITES, ubicándolo en el Apéndice I (CITES 2015).

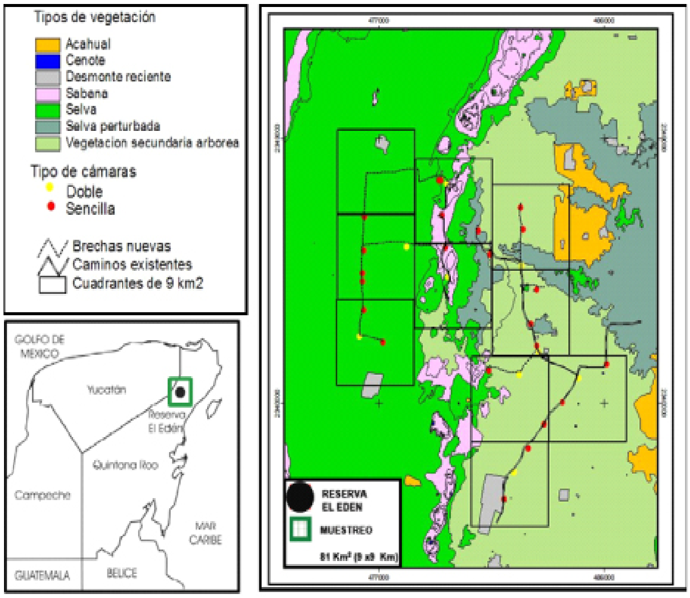

Figura 1. Zona de estudio con el diseño de muestreo propuesto por Chávez *et al.* (2007) cubriendo un área de 81 Km^2 y ubicación de las cámaras trampa para el ocelote (*Leopardus pardalis*) en el norte de Quintana Roo, México.

El norte de Quintana Roo presenta una serie de micro y macro hábitats que le permiten poseer una gran biodiversidad (Lazcano-Barrero *et al.* 1995). En la península de Yucatán se han registrado por lo menos 212 especies de mamíferos terrestres (Zaragoza-Quintana *et al.* 2016), y con al menos 404 especies de plantas vasculares (Schultz 2003). El estado de Quintana Roo es una de las áreas de impacto de fenómenos naturales, en la que se han reportado más de 10 huracanes en las últimas dos décadas que han tocado la zona norte y centro de la Península de Yucatán (CONAGUA 2006, 2012), además de que, en los últimos 30 años ha sufrido problemas de incendios, consumiendo más de 100,000 ha de selvas en la zona (CONAFOR, 2016). Asimismo, presenta problemas de intervención humana, entre los cuales se reconocen a la tala ilegal, cacería furtiva, cambio en el uso del suelo y aumento en las actividades turísticas (Lazcano-Barrero *et al.* 1995; Allen y Rincón 2003). El objetivo de este estudio fue generar información básica sobre la densidad poblacional, abundancia relativa, patrón de actividad y áreas mínimas de acción observadas del ocelote en la región norte de Quintana Roo, misma que ha estado sujeta a perturbaciones climáticas y antrópicas. El generar conocimientos sobre estos aspectos ecológicos pueden constituir un aporte fundamental para los planes de conservación que se realizan en la zona.

Materiales y Métodos

Área de Estudio. El área se sitúa al norte del estado de Quintana Roo, que incluye a la Reserva Ecológica el Edén (REE). La REE es la primera reserva ecológica privada dedicada a la investigación sobre la conservación y manejo de la biodiversidad en México y está ubicada a los 21° 13' N, -87° 11' W, en el Municipio de Lázaro Cárdenas (Lazcano-Barrero *et al.* 1995; Figura 1). La REE, cuenta con una superficie de 3,077 ha, y con al menos cinco tipos de vegetación: a) la selva mediana (vegetación de estructura mediana, semidecidua). b) Los acahuales de diferentes edades, (refiriéndose a vegetación secundaria con diferentes estados de sucesión a consecuencia de diferentes alteraciones antrópicas y climáticas provocados hace más de tres décadas). c) Bosque inundable (tintales y manchones de anonáceas que crecen en sitios inundables). d) Sabanas (que pueden ser áreas abiertas con palmas. e) Vegetación acuática (que crece en zonas pantanosas o cerca de los cenotes; Schultz 2003). Además, la REE pertenece a la región biológica de Yalahau (Gómez-Pompa *et al.* 2003) y una parte de las selvas tropicales, se encuentra bajo protección federal dentro del Área de Protección de Flora y Fauna Yum-Balam (Navarro *et al.* 2007). La zona registra una temperatura media anual de 24.7° C, con una precipitación anual de 1,200 mm (Allen y Rincón 2003).

Diseño de muestreo. Se realizó un muestreo sistemático utilizando trampas cámara digitales de las marcas Cuddeback (expert 3.0 Mpx®) y Moultrie (D40 4.0 Mpx®), ambos modelos contaron con flash visible y siguiendo el diseño del Censo Nacional del Jaguar (CENJAGUAR) propuesto por Chávez *et al.* (2007). Este consistió en instalar nueve celdas de 3 x 3 km^2 de aproximadamente 9 km^2 por celda. Lo que indica que en total se muestreo una área de 81 km^2 que incluye a la REE (Figura 1). Cada una de las celdas fue de igual tamaño y no más grande que el área de actividad de un ocelote hembra adulta que varía entre 0.7 y 9.6 km^2 (Di Bitetti *et al.* 2006; Sunquist y Sunquist 2002). En cada celda se colocaron tres estaciones de foto trampeo (dos sencillas y una doble), lo que da un total de cuatro cámaras trampa por celda (Figura 1). Se instalaron un total de 27 estaciones de foto-trampeo, 18 de las cuales fueron estaciones sencillas y nueve dobles (las estaciones dobles permitieron identificar a los individuos por ambos

Figura 2. Fotografías del lado derecho de dos ocelotes mostrando el patrón único de marcas en la piel, permitiendo así identificar a distintos individuos.

lados, importante por el patrón de manchas). Cada estación de foto-trampeo fue separada por lo menos un kilómetro entre estación sencilla o doble. Las cámaras fueron colocadas en diferentes puntos estratégicos para cubrir los tres tipos de vegetación más representativos de la zona: selva mediana, sabana y vegetación secundaria. Las trampas cámara estuvieron activas durante 60 días de foto-registros, iniciando el muestro en la tercera semana del mes de julio y terminando en la segunda semana del mes de septiembre del 2008. La duración total de muestreo no fue superior a 90 días en concordancia con el supuesto de población cerrada (Karanth y Nichols 1998). En total, se obtuvo un esfuerzo de muestreo de 2,160 días/trampa.

La identificación de cada individuo de ocelote (*L. pardalis*), se estableció por medio del patrón de machas o "marcas únicas" que presenta cada individuo en diferentes partes del cuerpo (Figura 2). Este método permitió diferenciar un individuo de otro, ya que las marcas únicas son patrones naturales de coloración característicos de los felinos manchados (Karanth y Nichols 1998). Se identificaron a los individuos por su sexo (presencia o ausencia de testículos).

Estimación de la abundancia. Para obtener el índice de abundancia relativa (IAR) de los ocelotes, se utilizó la formula sugerida por Maffei *et al.* (2002) y Sanderson (2004). IAR = (C/EM) x 1,000 días / trampa.

Dónde: C son las capturas o eventos independientes fotografiados; EM es el esfuerzo de muestreo total (número de cámaras trampa multiplicado por los días de muestreo) y 1,000 días/trampa (frecuencia de captura estandarizando a 1000 días/trampa). Para evitar sobre-estimaciones, se consideraron en los análisis sólo aquellos registros que fueran independientes con un lapso de separación de 60 min entre cada evento. Un registro independiente fue considerado como: 1) registros fotográficos consecutivos en donde no fuera posible identificar al ocelote como un individuo distinto, 2) registros fotográficos consecutivos de individuos diferentes completamente identificables y 3) registros fotográficos con varios individuos considerando a cada individuo como un evento. Posteriormente, se comparó el IAR por tipo de vegetación realizando una prueba de Chi-cuadrada (X^2) y así determinar la preferencia de hábitat (Byers *et al.* 1984; Krebs 1998), siguiendo la siguiente formula:

$$X^2 = \sum_{t=1}^{K} \frac{(O-E)^2}{E}$$

Dónde: E = frecuencia esperada de registros, O = frecuencia observada de registros y K = el número de hábitats comparados.

Patrón de actividad. Para determinar el patrón de actividad de los ocelotes, se utilizó y analizó el horario registrado en todas las fotografías como eventos independientes durante los 60 días de muestreo diferenciando entre machos y hembras. Los registros obtenidos se agruparon por intervalos de dos horas, así sucesivamente para las 24 h. Se consideró la siguiente clasificación para establecer el patrón de actividad: los registros al amanecer se consideraron entre las 06:00 to 8:00 horas, diurno 8:01 to 18:00, crepuscular 18:01 to 20:00, y nocturnos 20:01 to 05:59 horas. Para analizar diferencias en el patrón de actividad del ocelote, se utilizó la prueba de Wald del programa "ACTIVITY" (Rowcliffe 2015).

Estimación de la densidad. Una vez identificados individualmente a los ocelotes, fue posible obtener estimaciones de la densidad poblacional con modelos de captura-recaptura (Silver 2004). Para estimar la densidad de ocelotes, primero se estimaron las abundancias generadas por el programa "CAPTURE" (Karanth y Nichols 1998). Este programa analiza los datos (capturas-recapturas) y determina cuál es el modelo que mejor se ajusta a los datos. Además CAPTURE genera una probabilidad de captura para una población cerrada (p) para hacer estimaciones poblacionales, bajo dos supuestos: 1) la población debe ser cerrada y 2) todos los individuos tienen la misma probabilidad de captura mayor a cero (Silver 2004). Para seleccionar el modelo que mejor se ajusta a los datos, el valor obtenido varía entre 0 a 1, donde el valor más alto indica que el modelo tuvo un mejor ajuste. Posteriormente, la densidad de ocelotes se estimó dividiendo la abundancia relativa generada por CAPTURE entre el área efectiva de muestreo. Esta fue construida a partir del método del polígono

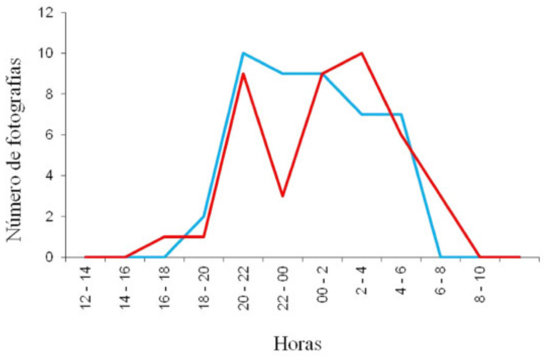

Figura 3. Patrón de actividad del ocelote (machos y hembras) en la zona norte de Quintana Roo, México. Las líneas correspondes en cada caso a ocelotes machos en azul y ocelotes hembras en rojo.

Tabla 1. Registro de frecuencias de ocurrencias de los 12 individuos de ocelote en los diferentes tipos de vegetación.

Individuo	Sexo	Fotografías	Tipo de vegetación
ocelote A	♂	13	vegetación secundaria
ocelote B	♂	7	
ocelote F	♀	3	
ocelote I	♀	1	
ocelote J	♀	1	
ocelote C	♂	12	selva mediana
ocelote D	♂	5	
ocelote E	♀	15	
ocelote G	♂	1	
ocelote L	♀	7	
ocelote H	♂	3	sabana
ocelote K	?	1	

Tabla 2. Índice de abundancia relativa (IAR) del ocelote y número de fotográficas por tipo de vegetación en el norte Quintana Roo, México. *IAR, índice de abundancia relativa (# fotos/días trampa*1000).

Individuo	Sexo	Fotografías totales	Tipo de vegetación	IAR* y valor de confianza
ocelote A, B, F, I, J	♂,♂, ♀, ♀, ♀	25	Vegetación secundaria	1.111 ± 0.22
ocelote H, K	?, ♂	4	Sabana	0.185 ± 0.09
ocelote C, D, E, G, L	♂, ♂, ♀, ♂, ♀	40	Selva mediana	1.852 ± 0.27

mínimo convexo (Kernohan *et al.* 2001), que incluyó todas las estaciones de muestreo que estuvieran en los extremos y adicionando a esta, una área de amortiguamiento. El área de amortiguamiento corresponde a la distancia media máxima de desplazamiento (MMDM, por sus siglas en inglés) recorrida por los ocelotes y capturados en dos o más estaciones. El área que cubrió el polígono formada por las cámaras trampa fue de 54 km^2, mientras que el área del polígono junto con la zona de amortiguamiento fue de 107.22 km^2.

Áreas mínimas de acción. Se estimó el área mínima observada de acción de seis ocelotes (cuatro machos y dos hembras) nombrados como macho M1, M2, M3, M4 y hembras H1 y H2 (sólo se consideraron estos ocelotes ya que fueron registrados en más de dos estaciones). Posteriormente, el área mínima observada de acción se estimó con el método del polígono mínimo convexo (Kernohan *et al*. 2001). Uniendo los puntos extremos donde los ocelotes fueron registrados. Se realizó una prueba de bondad de ajuste Chi-cuadrada (X^2) para evaluar diferencias en el área de acción entre machos y hembras.

Resultados

Identificación de ocelotes. Se obtuvieron 90 fotografías de ocelotes, de las cuales 68 fueron los registros fotográficos que se analizaron para su identificación. En total, se identificaron a 12 individuos adultos, cinco machos, seis hembras y un individuo al que no fue posible determinar el sexo, en donde cada ocelote fue nombrado en forma alfabética (A-L; Tabla 1). De los registros obtenidos, la frecuencia de ocurrencia indicó que la selva mediana obtuvo mayores registros fotográficos en comparación la vegetación secundaria y sabana (Tabla 1 y 2).

Estimación de Abundancias Relativas. El índice de abundancia relativa (IAR) fue estimado en los tres tipos de vegetación, encontrándose el mayor IAR para la selva mediana de 1.85 ± 0.27, mientras que la vegetación secundaria fue de 1.11 ± 0.22 y finalmente, el menor IAR fue para la sabana, de 0.185 ± 0.09. Además, la proporción de ocelotes hembras fue mayor para la vegetación secundaria, mientras que para la selva mediana y sabana la proporción de ocelotes hembras fue menor (Tabla 2).

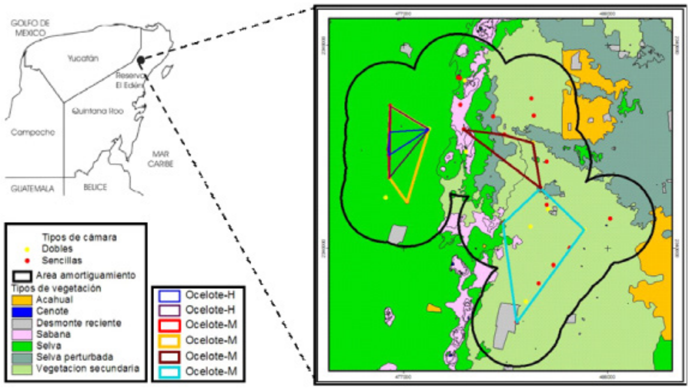

Figura 4. Ocelotes machos y hembras utilizados para crear el área de acción para la zona de muestreo en el norte de Quintana Roo, México.

Patrón de actividad. En relación al número de fotografías registradas, los ocelotes machos y hembras mostraron un pico de mayor actividad por la noche, para los machos fue alrededor de las 20:00 y 22:00 h., mientras que para las hembras se registró entre las 2:00 y 4:00 h. Las hembras presentaron dos picos en su patrón de actividad, ambos registrados por la noche. El primer pico fue de inactividad registrado entre las 22:00 y 00:00 h. El segundo, se registró regresando a su actividad entre las 00:00 y 2:00 h. Las hembras y los machos presentaron un periodo de inactividad registrado en el día. Para las hembras se registró entre las 10:00 y 16:00 h., mientras que para los machos se registró entre las 8:00 y las 18:00 h. La comparación del patrón de actividad entre períodos mostró que los ocelotes fueron significativamente más activos por la noche en comparación con los demás periodos del día ($W = 3.74$; $P < 0.05$).

Estimación de densidades. La densidad estimada para ocelotes sin diferenciar sexo fue de 14 ind/100 km^2, mientras que, la estimación para machos y hembras fue de 7 ind/100 km^2. De acuerdo con los resultados, el modelo de heterogeneidad M(h) con un valor de 1.00, fue el modelo que mejor se ajustó a los datos para evaluar la densidad de ocelotes en la zona de estudio (Tabla 3). Con la densidad obtenida de 14 ind/100 km^2, se estima cautelosamente que probablemente podrían existir unos 560 ocelotes para las 400,000 ha de selvas que corresponden a las Áreas de Conservación en la Península de Yucatán (ACPY), que incluyen al Parque Natural Reserva Ría Lagartos, Área de Protección de Flora y Fauna Yum Balam**,** Área Natural Protegida "El *Zapotal"*, la Reserva Ecológica el Edén, Reserva estatal Bocas de Dzilam, y región de Yalahau (Tabla 4).

Área *mínima de acción.* El área mínima observada de acción de los ocelotes machos fue de 4.63 km^2 y para hembras fue de 1.80 km^2 (Tabla 5). Al comparar los valores se encontró que entre machos y hembras existen diferencias estadísticamente significativas ($X^2 = 259.47$; g. l. = 1; $P < 0.05$). El área de acción de machos es 2.57 veces mayor al de las hembras, con una sobreposición entre individuos del mismo y de distintos sexos (Figura 4).

Discusión

Preferencia de hábitat, patrón de actividad y área mínima de acción. Los ocelotes se pueden encontrar en diversos tipos de hábitats, que van desde bosques húmedos, sabanas, bosques deciduos, zonas con matorral, zonas perturbadas, selvas altas y medianas, además de que, se han registrado en diferentes altitudes desde los 0 a los 3,800 msnm (Maffei *et al.* 2005; Mar-

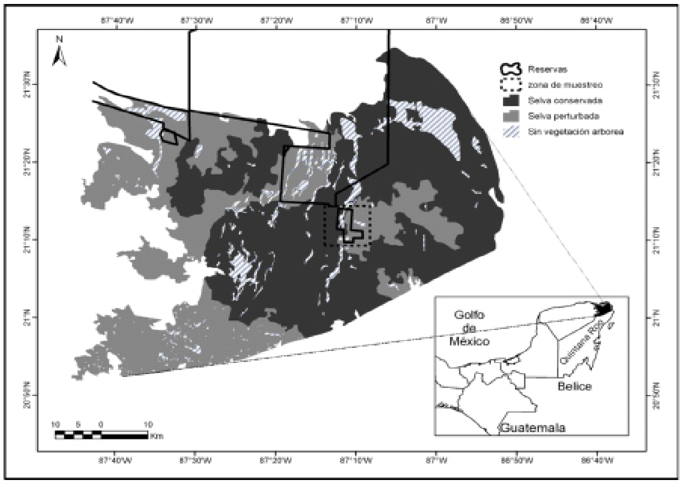

Figura 5. Áreas Naturales Protegidas de carácter privadas y nacionales, utilizadas para hacer una estimación cautelosa de la población del ocelote (*Leopardus pardalis*) en la zona norte de la Península de Yucatán.

tínez-Calderas *et al*. 2011; Valdez-Jiménez *et al*. 2013; Aranda *et al*. 2014; Pérez-Irineo y Santos-Moreno 2014). Sin embargo, Sunquist y Sunquist (2002), Emmons (1988) y Emmons *et al.* (1989), sugieren que los ocelotes prefieren las coberturas vegetales densas, ya que estas les proporciona hábitats de refugio ante posibles depredadores y del mismo hombre, además de sitios de descanso y de seguridad para proteger a sus crías, así como de lugares para la búsqueda de alimento. Jackson *et al.* (2005), realizaron un trabajo por medio de telemetría en Texas y comprobaron que los ocelotes prefieren aquellos parches de vegetación con coberturas densas.

En el presente estudio, los ocelotes prefirieron aquellos hábitats más conservados, como es el caso de la selva mediana subperennifolia, visitando menos los sitios abiertos tales como la vegetación secundaria y la sabana. Esto sugiere la importancia que tiene la selva mediana subperennifolia, ya que ésta, se encuentra con menor grado de perturbación humana (*e. g*., cambio del uso del suelo, incendios y tala ilegal) y por ende posee una cobertura vegetal conservada que pudiera proporcionar lugares seguros para su resguardo, alimentación y hábitats de paso, principalmente. En este sentido, se ha documentado que uno de los principales problemas de conservación del ocelote es la destrucción y pérdida paulatina de las áreas con cobertura vegetal densa (Emmons *et al*. 1989; Laack 1991). Es por ello que una estrategia de conservación debe incluir la protección de áreas con cobertura vegetal lo más densa posible dentro y fuera de áreas naturales protegidas para garantizar que estos felinos puedan tener hábitats disponibles para sobrevivir a medio y lanzo en la región y en México.

En relación al periodo de actividad, se reporta que pueden estar activos durante todo el día, con una mayor actividad por las noches (Di Bitetti *et al*. 2006; Maffei *et al*. 2005, Pérez-Irineo y Santos-Moreno 2014), además de que, su actividad también depende de la actividad de sus presas potenciales (*e. g*., roedores, reptiles y pequeños mamíferos y aves; Murray y Gardner 1997). Nuestros registros de foto captura sugieren que los ocelotes presentan un periodo de actividad tanto de día como de noche, pero que son preferentemente nocturnos.

Las estimaciones de las áreas de acción de los ocelotes muestran que estas pueden variar entre 3.5 km^2 y 17.7 km^2 para los machos y entre 0.7 km^2 y 14.6 km^2 para las hembras (Emmons *et al*. 1989). Navarro (1985), reporta que los machos presentan una área de acción de 2.52 km^2 y para las hembras de 2.07 km^2, mientras que el estudio realizado por Martínez-Meyer (1997), sugiere que las hembras tienen un área de acción superior a la de los machos con 5.68 km^2 y 5.23 km^2, respectivamente. Se reporta, que los machos suelen tener un área de acción más amplia con respecto a las hembras, lo cual podría deberse por una lado a que los machos tienen que defender su territorio y por el otro para la búsqueda de hembras para poder reproducirse (Murray y Gardner 1997; Sunquist 1991). Además, existe evidencia en la que se sugiere que el área de acción de los ocelotes puede ser compartida por individuos de ambos sexos, es decir la sobreposición se puede presentar entre hembras que tengan afiliación por la línea materna (Murray y Gardner 1997).

Aquí reportamos con base a nuestros registros que el área mínima de acción observada del ocelote en el norte de Quintana Roo se encuentra con valores promedio de los resultados reportados en otras áreas y tipos de hábitats (Di Bitetti *et al.* 2006; Emmons *et al*. 1989; Laack 1991; Navarro 1985; Maffei *et al*. 2005; Martínez-Meyer 1997; Salom 2005; Tabla 5). Además, encontramos que existe una sobreposición de las áreas mínimas observadas de acción entre ocelotes machos y hembras, no encontrando el patrón entre ocelotes machos, lo que podría

Tabla 3. Resumen de los resultados obtenidos a partir del método de captura-recaptura mediante el uso de foto-trampeo. Nota: para el caso de la Sabana y por los escasos datos de captura-recaptura, no fue posible hacer una estimación.

Categorías	PCE	PC	DE	MMDM (m)	Amt (km^2)	M	P
Machos	0.066	7 ± 1.19	7	4,510	39.33	M(h)	z = -0.883; *P* = 0.188
Hembras	0.073	7 ± 2.12	7	2,720	20.56	M(h)	z = 0.150; *P* = 0.559
Tipo de vegetación							
Selva Mediana	0.100	6 ± 1.63	23	3,285	26.08	M(h)	z = 0.534; *P* = 0.703
Vegetación secundaria	0.043	7 ± 2.12	8	3,886	63.47	M(h)	z = -0.816; *P* = 0.207
Sabana							
TOTAL	0.053	15 ± 2.59	14	3,542	107.22	M(h)	z = -0.383; *P* = 0.350

PCE = Probabilidad de captura estimada; PC = Población estimada con CAPTURE; DE = Densidad estimada (individuos/100 km^2); MMDM = Promedio de las distancias máximas de desplazamiento; Amt = Área de amortiguamiento; M=Modelo; M (h) = Modelo de JACKNIFE, probabilidad de captura heterogénea; P = Prueba de población cerrada

Tabla 4. Estimación del tamaño poblacional de ocelotes (sin diferenciar sexo 14 ind/100km^2 (DA), de machos y hembras 7 ind/100km^2 (DB)) para las áreas de conservación privadas y nacionales al norte de la Península de Yucatán.

Áreas de Conservación	Sup. km^2	DA	DB
Áreas de conservación en la Península de Yucatán (ACPY)	1,400	196	98
Región Yalahau y Ría Lagartos (incluyendo ACPY)	4,000	560	280

ACPY: Parque Natural Reserva Ría Lagartos, Área de Protección de Flora y Fauna Yum Balam, Área Natural Protegida "El Zapotal", la Reserva Ecológica el Edén, Reserva estatal Bocas de Dzilam, y región de Yalahau, superficie en km^2 tomado y modificado de Faller *et al*. 2006.

coincidir parcialmente con lo reportado por Murray y Gardner (1997) y Sunquist (1991). Por tanto, y con base a lo sugerido por estos autores, cabe la posibilidad de considerar que las hembras estuvieran en período reproductivo, o del cuidado de sus crías, ya que se encontró una sobreposición del área mínima de acción entre hembras y machos. También, encontramos que los ocelotes machos no presentaron una sobreposición del área mínima de acción (Figura 4). Cabe mencionar que, cuatro de las seis estimaciones del área mínima de acción de los ocelotes se registraron en la selva mediana. Estas diferencias pueden estar relacionadas a la preferencia del tipo de hábitat, ya que los movimientos de los ocelotes tienden a concentrarse en aquellas zonas que les proporcionen más oportunidades de recursos alimenticios y de refugio (Martínez-Meyer 1997).

Estimación poblacional. La densidad poblacional de ocelotes estimada sin diferenciar el sexo fue de 14 ind/100 km^2. Esta densidad estimada es similar con lo registrado en otros sitios como Argentina y Guatemala (Di Bitetti *et al*. 2006; Moreira *et al*. 2007), pero diferente a lo registrado en Costa Rica, Bolivia, Texas, Belice y Los Chimalapas en México (Dillon y Kelly 2007, 2008; Maffei *et al*. 2005; Salom 2005; Haines *et al*. 2006; Pérez-Irineo y Santos-Moreno 2014), ya que en estos lugares presentan densidades superiores. Estas diferencias en las densidades estimadas podrían variar en el espacio y tiempo, además de estar relacionadas a factores metodológicos, tales como: número de estaciones de muestreo (*e. g*., sencillas o dobles), días/trampa, distancia entre estaciones de trampeo, y temporada de muestreo (*e. g*., lluvias o secas). Aunado a esto, las densidades estimadas en cada región podrían estar determinadas por disturbios climáticos y antrópicos (*e. g*. incendios, huracanes), tipo de hábitat (*e. g*., bosques de pino, bosques tropicales, selvas perennifolias, matorrales), por características del paisaje (*e. g*., áreas con pérdida y modificación de sus coberturas forestales y áreas con algún grado de protección), y por disponibilidad de recursos alimenticios, ocasionando que los estudios realizados en otras áreas y tipos de hábitats no sean comparables (Dillon y Kelly 2007, 2008).

Tabla 5. Estimación del área de acción de ocelotes en diferentes sitios y del presente estudio.

Lugar	**Sexo (km^2)**		**Método**	**Autor**
	Machos	**hembras**		
Perú	5.9	1.6	Telemetría	Emmons *et al*. 1989
Texas, EE. UU.	6.25	2.87	Telemetría	Laack 1991
Texas, EE. UU.	2.52	2.07	Telemetría	Navarro 1985
Jalisco, México	5.23	5.68	Telemetría	Martínez-Meyer 1997
Costa Rica	6.19		Trampas cámara	Salom 2005
Argentina	13.41	6.01	Telemetría	Di Bitetti *et al*. 2006
Bolivia	3.1	2.45	Telemetría	Maffei *et al*. 2005
Quintana Roo	4.63	1.8	Trampas cámaras	Presente estudio

Ávila-Nájera *et al*. (2015), realizaron un estudio en nuestra misma zona de estudio durante los años 2008, 2010, 2011, y 2012, en la que reportan una densidad de 13.86 ind/100 km^2 para el 2010 y para el mismo periodo de muestro del presentado en nuestro estudio. Sin embargo, para los años posteriores reportan una densidad por debajo de la reportada para el 2010. Esto probablemente se deba a aspectos tales como: i) diferentes periodos de muestreo, ii) presencia de alteraciones antrópicas y climáticas (*e. g*., incendios forestales y huracanes), que promueven la dispersión de las especies, y iii) movilidad de los ocelotes hacia otros hábitats para la búsqueda de alimento, reproducción y cuidado de crías. Por tanto, se infiere que estos factores, pudieran afectar la dinámica de la especie dentro del mismo espacio y tiempo provocando una cierta reacción en el cambio del patrón de movimiento ante los efectos antrópicos y climáticos.

Áreas de conservación. En la zona norte de la Península de Yucatán existen aproximadamente unas 400,000 ha de selvas protegidas para su conservación (Faller *et al*. 2006), y que han estado sujetas a alteraciones antrópicas moderadas a severas (*e. g*., apertura de diversas carreteras, tales como la autopista Cancún-Mérida e Ideal-Cancún). Esta perturbación puede provocar que la zona se encuentre con problemas de conectividad con las selvas del sur de la Península (*e. g*., Calakmul, Balam ka`ax, Balam ku, Balam kim y Sian Kaán). Esta falta de conectividad podría inducir a un aislamiento poblacional de ocelotes y otros grupos de vertebrados terrestres, y que, a mediano y largo plazo pueda reflejarse en problemas de endogamia, enfermedades y en otros casos la extirpación local.

Considerando que la estimación obtenida de ocelotes fue de 14 ind/100 km^2, es posible proporcionar un dato del posible tamaño poblacional del ocelote en el norte de la Península de Yucatán. De tal manera que se podría hacer una estimación con cautela de una población de ocelotes, en la que podrían existir 560 ocelotes en las 400,000 ha de selvas que cubren las Áreas Naturales Protegidas (Figura 5, Tabla 4). Sin embargo, consideramos la importancia de realizar estudios más profundos en el tiempo y espacio en áreas adyacentes con hábitats similares a los estudiados para obtener estimaciones más sólidas y robustas sobre la densidad poblacional de ocelotes en la zona norte de la Península.

A modo de conclusión, el presente estudio brinda información indispensable sobre algunos aspectos de la ecología del ocelote, entre esta, encontramos que los ocelotes presentan un patrón de actividad nocturno y su actividad empieza a disminuir en el amanecer, donde las hembras permanecen activas más horas que los machos. El índice de abundancia relativa indica que los ocelotes son más abundantes en la selva mediana seguido de vegetación secundaria y por último la sabana. Nuestros resultados muestran que existe una sobreposición de las áreas mínimas de acción observada de los ocelotes entre individuos de sexos diferentes, en donde,

Tabla 6. Estimación de la densidad de ocelotes para diferentes sitios de muestreo y del presente estudio. Dias de muestreo (DM), Densidad (ind/100km^2; Den), Estaciones de trampeo (ET).

Sitio de Estudio	DM	Den	ET	Autor
Bolivia	60	30-56		Maffei *et al.* 2005
Costa Rica	90	23.57	12	Salom 2005
Texas	60-76	30.00		Haines *et al.* 2006
Argentina	90	13.36	36	Di Bitetti *et al.* 2006
Belice		22.85	19	Dillon y Kelly 2007
Guatemala	21	14.70	21	Moreira *et al.* 2007
Belice	30-90	25.88	17	Dillon y Kelly 2008
Argentina	96	17.60	42	Di Bitetti *et al.* 2008
Chimalapas, México		22-38	29	Pérez-Irineo y Santos-Moreno 2014
N. Quintana Roo	65-82	1.4-13.8	22-27	Ávila-Nájera *et al.* 2015
N. Quintana Roo	60	14.00	27	Presente estudio

el tamaño promedio del área mínima de acción es mayor para los machos. Finalmente, este trabajo representa un avance relevante sobre la situación del ocelote (*L. pardalis*) en la REE y su área de influencia, constituyendo una línea base fundamental para hacer una comparación en áreas adyacentes que están sujetas a fuertes presiones climáticas y antrópicas.

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Literatura citada

Allen, M. F, y E. Rincón. 2003. The Changing Global Environment and the Lowland Maya: Past Patters and Current Dynamics**.** Pp. 13-29 in The Lowland Maya Area: three millennia at the human-wildland interface. The Haworth Press. New York, EE. UU.

Aranda, M., F. Botello, E. Martínez-Meyer, y A. Pineda. 2014. Primer registro de ocelote (*Leopardus pardalis*) en el Parque Nacional Lagunas de Zempoala, Estado de México y Morelos, México. Revista Mexicana de Biodiversidad 85:1300–1302.

Aranda, M. 2005. Ocelote. Pp. 359-361, en Los mamíferos silvestres de México (Ceballos, G., y G. Oliva, eds.). CONABIO, Fondo de Cultura Económica. Ciudad de México, México.

Ávila-Nájera, D. M., C. Chávez, M. A. Lazcano-Barrero, S. Pérez-Elizalde, y J. L. Alcántara-Carbajal. 2015. Estimación poblacional y conservación de felinos (Carnivora: Felidae) en el norte de Quintana Roo, México. Revista de Biología Tropical 63:799-813.

Bárcenas, H., y R. A. Medellín. 2010. Ocelot (*Leopardus pardalis*) in Aguascalientes, Mexico. Southwestern Naturalist 55:447–449.

Byers, R. C., R. K. Steinhorst, y P. R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. Journal of Wildlife Management 48:1050-1053.

Chávez, C., G. Ceballos, R. Medellín, y H. Zarza. 2007. Primer censo nacional del jaguar. Pp. 133-141 in Conservación y Manejo del Jaguar en México estudios de caso y perspectivas. CONABIO-UNAM-Alianza WWF, Telcel. Ciudad de México, México.

Comisión nacional forestal (conafor). 2016. Incendios Forestales Generalidades, México. Disponible en: http://www.conafor.gob.mx/programas_nacionales_forestales/incendios/

Convención Sobre el Comercio Internacional de Especies Amenazadas de Fauna y Flora Silvestres (CITES). 2015. Convención sobre el Comercio Internacional de Especies Amenazadas de Fauna y Flora Silvestres (CITES). Apéndices I, II y III en vigor a partir del 24 de julio de 2010. http://www.cites.org/. Última visita: 30 marzo 2015.

Comisión Nacional del Agua (conagua). 2006. Análisis de las temporadas de huracanes de los años 2004 y 2005 en México, Comisión Nacional del Agua. Ciudad de México, México.

Comisión Nacional del Agua (conagua). 2012. Análisis de las temporadas de huracanes de los años 2009, 2010 y 2011 en México, Comisión Nacional del Agua. Ciudad de México, México.

Di Bitetti, M. S., A. Paviolo, C. De Angelo, y Y. Di Blanco. 2008. Local and continental correlates of the abundance of a neotropical cat, the ocelot (*Leopardus pardalis*). Journal of Tropical Ecology 24:1-12.

Di Bitetti, M. S., A. Paviolo, y C. De Angelo. 2006. Density, habitat use and activity patterns of ocelots (*Leopardus pardalis*) in the Atlantic Forest of Misiones, Argentina. Journal of Zoology 270:153–163.

Dillon, A., y M. Kelly. 2007. Ocelot *Leopardus pardalis* in Belize: the impact of trap spacing and distance moved on density estimates. Oryx 41:469-477.

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

Emmons, L. H., P. Sherman, D. Bolster, A. Goldizen, y J. Terborgh. 1989. Ocelot behavior in moonlight. Pp. 233-242 in Advances in Neotropical Mammalogy. Sandhill Crane Press. Gainesville, EE. UU.

Emmons, L. H. 1988. A field study of ocelots (*Felis pardalis*) in Peru. Reviewd´Ecologie (Terre Vie) 43:133-157.

Faller, J. C., C. Chávez, S. Johnson, y G. Ceballos. 2006. Estimación de una población de jaguar en el norte de la Península de Yucatán. Pp. 259 in Conservación y manejo del jaguar en México: estudios de caso y perspectivas. Conabio-Alianza WWF. Telcel-UNAM. Ciudad de México, México.

Galindo-Aguilar, R. E., L. Cacelin-Castillo, O. C. Rosas-Rosas, M. G. Bravo-Vinaja, J. L. Alcántara-Carbajal, y V. Vázquez-García. 2016. First records of ocelot in tropical forests of the Sierra Negra of Puebla and Sierra Mazateca de Oaxaca, Mexico. Therya 7:205–211.

García-Bastida, M., F. Martínez-De La Fuente, A. Vázquez-Venegas, y J. L. Peña-Mondragón. 2016. A new record of ocelot in Parque Ecológico. Therya 7:1–6.

Gómez-Pompa, A., M. F. Allen, S. Fedick, y J. J. Jiménez-Osorio. 2003. The Lowland Maya Area. Three Millennia at the Human-Wildland Interface Binghamton. The Haworth Press. New York, EE. UU.

Haines, A., J. Janecka, M. Tewes, L. Grassman, y P. Morton. 2006. The importance of private lands for ocelots (*Leopardus pardalis*) conservation in the United States. Oryx 40:1-5.

Hernández-Flores, S. D., G. Vargas-Licona, y G. Sánchez-Rojas. 2013. First records of the Ocelot (*Leopardus pardalis*) in the state of Hidalgo, Mexico. Therya 4:99–102.

Iglesias, J., V. Sánchez-Cordero, G. Magaña-Cota, R. Bolaños, M. Aranda, R. Hernández, y F. Botello. 2008. Noteworthy records of margay, *Leopardus wiedii* and ocelot, *Leopardus pardalis* in the state of Guanajuato, Mexico. Mammalia 72:347–349.

International Union For Conservation of Nature (UICN). 2015. The IUCN red list of threatened species. Version 2014.3. http://www.iucnredlist.org. Última visita: 6 enero 2015.

Jackson, V. L., L. L. Laack, y E. G. Zimmerman. 2005. Landscape metrics associated with hábitat use by ocelots on south Texas. Journal of Wildlife Management. 69:733-738.

Karanth, K. U, y J. D. Nichols. 1998. Estimation of tiger densities in India using photographic captures and recaptures. Ecology 79:2852-2862.

Kernohan, B. J., R. A. Gitzen, y J. J. Millspaugh. 2001. Analysis of animal space use and movement. Pp. 125-166 en Radio Tracking and Animal Populations. Academic Press. San Diego, EE. UU.

Krebs, C. H. 1998. Ecological Methodology. 2^{da}. Ed. Harper y Row Publishers. New York, EE. UU.

Laack, L. L. 1991. Ecology of the ocelot (*Felis pardalis*) in south Texas. Thesis of master. Texas University. Kingsville, EE. UU.

Lazcano-Barrero, M. A., M. Vázquez-Sánchez, I. March, H. Núñez, y M. Fuller. 1995. La región de Yalahau: propuesta para el establecimiento de una zona de conservación y desarrollo sostenible en el norte de Quintana Roo, CECRN, Colegio de la Frontera Sur. Chetumal, México.

Maffei, L., E. Cúellar, y A. Noss. 2002. Uso de trampas cámara para la evaluación de mamíferos en el ecotono Chaco-Chiquitanía. Revista Boliviana de Ecología y Conservación Ambiental 11:55-65.

Maffei, L., A. J. Noss, E. Cuéllar, y D. I. Rumiz. 2005. Ocelot (*Felis pardalis*) population densities, activity, and ranging behaviour in the dry forests of eastern Bolivia: data from camera trapping. Journal of Tropical Ecology 21:349–353.

Martínez-Meyer, E. 1997. Estudio ecológico del ocelote (*Leopardus pardalis*) en la zona de Chamela, Jalisco, México. UNAM, Tesis de Maestría. Ciudad de México, México.

Martínez-Calderas, J. M., O. C. Rosas-Rosas, J. F. Martínez-Montoya, L. A. Tarango-Arámbula, F. Clemente-Sánchez, M. M. Crosby-Galván, y M. D. Sánchez-Hermosillo. 2011. Distribución del ocelote (*Leopardus pardalis*) en San Luis Potosí, México. Revista Mexicana de Biodiversidad 82:997-1004.

Moreira, J., R. García, R. Mcnab, T. Dubón, F. Córdova, y M. Córdova. 2007. Densidad de ocelotes (Carnivora: *Leopardus pardalis*) en la parte este del Parque Nacional Mirador Río Azul, Guatemala. WCS-Guatemala. Petén, Guatemala.

Murray, J. L., y G. L. Gardner. 1997. *Leopardus pardalis*. Mammalian Species 548:1-10.

Navarro, D. 1985. Status and distribution of the ocelot (*Felis pardalis*) in South Texas. Tesis de Maestría. Texas University. Kingsville, EE. UU.

Navarro, C. J., J. F. Remolina, y J. J. Pérez. 2007. El jaguar en Yum Balam y el Norte de Quintana Roo. Pp. 123-132 in Conservación y manejo del jaguar en México: estudio de caso y perspectivas. CONABIO, Alianza WWF, Telcel, Universidad Nacional Autónoma de México. Ciudad de México, México.

Pérez-Irineo, G., y A. Santos-Moreno. 2014. Density, distribution, and activity of the ocelot *Leopardus pardalis* (Carnivora: Felidae) in Southeast Mexican rainforests. Revista de Biología Tropical 62:1421-1432.

Rowcliffe, M. 2015. Package "activity" Animal Activity Statistics. https://cran.r-project. org/web/packages/activity/index.html

Salom, R. 2005. Ecología del jaguar (*Panthera onca*) y el Manigordo (*Leopardus pardalis*) carnivora: felidae, en el Parque Nacional Corcovado, Costa Rica. Tesis de Maestría. Universidad de Costa Rica. San José, Costa Rica.

Semarnat (Secretaria del Medio Ambiente y Recursos Naturales). 2010. Norma Oficial Mexicana NOM-059-ECOL-2010, Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo. Ciudad de México, México.

Sanderson, J. G. 2004. Protocolo para Monitoreo con Cámaras para Trampeo Fotográfico. Tropical Ecology Assessment and Monitoring (TEAM) Initiative. The Center for Applied Biodiversity Science (CABS). Conservación Internacional. Watkinsville, EE. UU

Schultz, P. G. 2003. Structure and Diversity of the Forests at the El Eden Ecological Reserve. Pp. 91-114, in The Lowland Maya Area: three millennia at the human-wildland interface. The Haworth Press. New York. EE.UU.

Silver, S. 2004. Estimando la abundancia de jaguares mediante trampas-cámara. Wildlife Conservation Society. New York, EE. UU.

Soisalo, M. K., y M. C. Cavalcanti. 2006. Estimating the density of jaguar population in the Brazilian Pantanal using camera-traps and capture-recapture sampling in combination with GPS radio telemetry. Biological Conservation 129:487-496.

Sunquist, M., y F. Sunquist. 2002. Wild Cats of the world, The University of Chicago Press. Chicago, EE.UU.

Sunquist, M. 1991. The ecology of ocelot: the importance of incorporating life history traits into conservation plans. Pp.117-128 in Felinos de Venezuela: Biología, Ecología y Conservación. Fudeci, Venezuela.

Valdez-Jiménez, D., C. M. García-Balderas, y G. E. Quintero-Díaz. 2013. Presencia del ocelote (*Leopardus pardalis*) en la "Sierra del Laurel", municipio de Calvillo, Aguascalientes, México. Acta Zoológica Mexicana (n. s.) 29:688–692.

Zaragoza-Quintana, E. P., J. M. Pech-Canché., J. E. Sosa-Escalante., S. Hernández-Betancourt, L. S. León-Paniagua, y M. C. MacSwiney. 2016. Small rodents in the Yucatan Peninsula: knowledge and perspectives in 114 years of research. Therya 7:299-314.

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Habitat use by the Antillean manatee (*Trichechus manatus*) during an extreme dry season in an urban lake in Tabasco, Mexico

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There are three important manatee areas in Mexico: the coasts of the State of Quintana Roo; the freshwater systems within the lower basin of the Grijalva-Usumacinta rivers, which host the largest manatee population; and the rivers of central and southern Veracruz. The Antillean manatee (*Trichechus manatus manatus*) is a threatened species throughout its range. In the Grijalva-Usumacinta region, two of the current threats to manatees are the effects of extremely dry periods and geographical isolation. The objective of the study was to evaluate the behavior and habitat use of the landlocked manatee population inhabiting Laguna de las Ilusiones, Villahermosa, Tabasco, under fortuitous dry conditions, to conduct an evaluation and implement a monitoring plan for landlocked manatees. In this work, we gathered information on the differential use of the lake, and on whether this use is related to the known habitat characteristics that govern the distribution of manatees. Using VHF tags, we followed the activities of four manatees (three females and one male) to characterize and quantify four behaviors, namely feeding, resting, exploring, and traveling, between April and August 2007. We built Kernel polygons for the 25, 50, 75, and 95 % of the utilization distribution (UD). We modeled the habitat using a binary logistic regression and explored the association between the tagged manatees using Cole's simple coefficient of association. Manatees were concentrated mainly to the northeast of the lake. The best feeding logistic model included depth, distance to the the shore, tree cover, and wind speed (Table 1), and yielded differences between periods ($H = 9.85$, $P = 0.007$, Figure 5). The logistic models fit poorly for resting, exploring, and traveling (Table 1). The resting model included distance to the the shore, tree cover, and company, and yielded differences between periods ($H = 6.68$, $P = 0.035$). Traveling included depth, cloud cover, and human activities, and yielded differences between periods ($H = 7.55$, $P = 0.023$). Exploration included depth and company, and did not differ between periods ($H = 1.55$, $P = 0.461$). We had the opportunity to assess these behaviors under dry conditions, and our findings are not necessarily applicable to the rainy season. The northern portion of the lake is an embayment connected to the central zone by a 50 m-wide shallow channel, which limited the movement of manatees. Higher food availability and stress avoidance might make manatees choose this area. Feeding was better modeled by the habitat characteristics included in the study. Feeding increased slightly in the evenings. Exploring and traveling were the behavior types observed most frequently in manatees; maybe they were moving across food patches or known areas. Manatee social encounters are reported as short-term and sporadic, but in this study manatees were observed in groups during nearly half of the observation time. When the availability of grasses and aquatic plants is low, manatees increase their consumption of other food items like mango fruits. Based on the findings reported here and under dry conditions, habitat enrichment will be helpful for this landlocked manatee population and those in other areas where seasonal contrasts is observed.

En México existen tres áreas importantes de distribución para el manatí: las costas del estado de Quintana Roo, los sistemas de agua dulce en la cuenca baja de los ríos Grijalva-Usumacinta y los ríos del centro y sur de Veracruz. El manatí Antillano (*Trichechus manatus manatus*) es una especie amenazada en toda su distribución. En la región Grijalva-Usumacinta se albergan las poblaciones más grandes de manatí y se reconocen dos problemas ecológico-ambientales como es el efecto de la sequía prolongada y el aislamiento geográfico de las poblaciones. El objetivo de este trabajo fue evaluar el comportamiento y uso de hábitat de la población de Laguna de las Ilusiones, Villahermosa, Tabasco, bajo una sequía fortuita, para implementar un plan de monitoreo y evaluación de poblaciones aisladas de manatíes. Con esta investigación se obtiene información del uso diferencial de la laguna y si este uso se relaciona con características del hábitat que determinan su distribución. Mediante el uso de radiotransmisores se dio seguimiento de actividad a tres hembras y un macho, para caracterizar y cuantificar sus comportamientos: alimentación, descanso, exploración y desplazamiento en los meses de abril y agosto 2007. Se realizaron modelos de regresión logística de la ocurrencia de las conductas en relación a características del hábitat y polígonos de distribución de uso (U. D.) de 25, 50, 75 y 95 %. Para explorar la asociación entre los manatíes marcados se utilizó el coeficiente simple de asociación de Cole. La ocurrencia se concentró al noreste de la laguna. El mejor modelo logístico de alimentación incluyó profundidad, distancia a la orilla, cubierta arbolada, y viento (Tabla 1), difiriendo entre horarios ($H = 9.85$, $P = 0.007$, Figura 5). Los modelos de otros comportamientos tuvieron poco ajuste (Tabla 1). El modelo del descanso incluyó distancia a la orilla, cobertura arbolada y compañía, difiriendo temporalmente ($H = 6.68$, $P = 0.035$). El desplazamiento incluyó profundidad, nubosidad y actividad humana, difiriendo entre periodos ($H = 7.55$, $P = 0.023$). La exploración incluyó profundidad y compañía, sin diferencia temporal ($H =1.55$, $P = 0.461$). El brazo norte de la laguna se conecta a través de un canal somero, que en secas puede limitar el movimiento de los manatíes. Mayor disponibilidad de alimento en secas y evasión del estrés pueden llevar a los manatíes a esta área. La exploración y desplazamiento fueron los comportamientos más frecuentes, quizá moviéndose entre parches de alimento o entre áreas conocidas. Casi en la mitad de las observaciones los manatíes estuvieron acompañados. Cuando hay baja disponibilidad de pastos o vegetación acuática, los manatíes usan alimentos alternativos. El enriquecimiento del hábitat, sería muy útil para esta y otras poblaciones aisladas.

Keywords: behavior; habitat modeling; landlocked populations; management requirements; resource availability; spatial distribution.

Introduction

There are three key manatee distribution areas in Mexico: the river systems in the southern Gulf of Mexico (Tabasco, northern Chiapas and southwestern Campeche); the coast of Quintana Roo, mainly in the central and southern areas, and the low portions of rivers in central and southern Veracruz (CONANP 2010). The lower basin of the Grijalva and Usumacinta rivers is believed to host the largest manatee population in Mexico (Lefevre *et al.* 2001; Marsh *et al.* 2012).

The Antillean manatee (*Trichechus manatus manatus*) is considered a species endangered of extinction throughout its distribution range (Self-Sullivan and Mignucci-Giannoni 2008). The Mexican Official Standard lists the manatee in this same category (Mexican Official Standard NOM-059-SEMARNAT-2010, Official Journal of the Federation 2010). Manatees face various problems, including an extensive historical hunting that still persists, mainly for subsistence consumption (Smith-Cavros *et al.* 2012). Other issues are the deaths resulting from the interaction with human activities, habitat loss and alteration of wilderness areas associated to changes in land use for agriculture, livestock raising, and rural or urban development (CONANP 2010). An issue that is unique to this species is the partial or total isolation of local populations due to natural or anthropogenic changes in the topology of the Mexican river systems (CONANP 2010; Estrada-Loreto *et al.* 2013). The implementation of a monitoring plan for these landlocked populations requires assessing their behavior and habitat use. Decision-makers, authorities that manage conservation aspects, need a scientific support to plan and execute management initiatives on those populations (CONANP 2010). One such isolated population of *T. m. manatus* inhabits Laguna de las Ilusiones in Villahermosa, Tabasco, Mexico, a city with a human population of 64,000 inhabitants (INEGI 2010). In this lake, the protection of the manatee population is a top priority, but efforts to characterize it have been made only in the past decade (Pablo-Rodríguez and Olivera-Gómez 2012). The estimated population size of manatees in the lake is 18 to 39 individuals (Pérez-Garduza 2013).

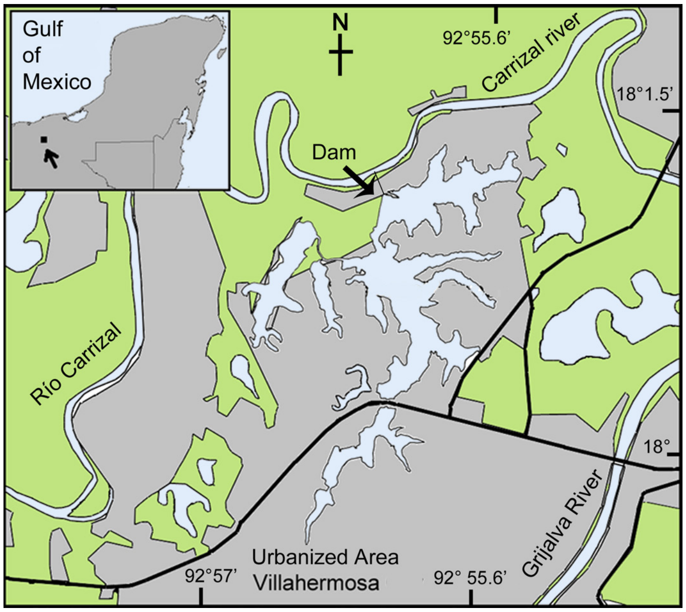

Figure 1. Laguna de las Ilusiones, in the city of Villahermosa, Tabasco, Mexico.

Knowledge about habitat use by the Antillean manatee (*T. m. manatus*) in the landlocked environment of Laguna de las Ilusiones, coupled with the atypical drought conditions under which this study was conducted, allowed us to document the general behavior of the species, and is a useful model for the development of management techniques.

Materials and Methods

Study area. Laguna de las Ilusiones (Figure 1) is an enclosed lake, irregular in shape, with a water mirror that stretches across approximately 260 hectares. It is a shallow water body, with depths that do not reach 5 m, mainly of less than 3.5 m. This lake is located within the city of Villahermosa, Tabasco (17° 59′ 22″, 18° 01′ 22″ N, -92° 55′ 20″, -92° 56′ 40″ W, at 10 m). The lake is a State of Tabasco's Protected Natural Area (Official Journal of the State of Tabasco, February 3, 1995). Until the early 1980s, it was connected to the Carrizal river, a tributary of the Grijalva river, but the connections were blocked as a result of urban development. Today, a small lock regulates the water level in the lake, allowing a partial flow toward the Carrizal river (INEGI 2010).

The climate in the area is warm and humid, with an annual temperature range of 24 °C to 28° C and precipitation between 1,500 and 2,000 mm/year (INEGI 2010). Soils in the region are Cenozoic sedimentary and fluvisols, which promote the growth of wetland vegetation (INEGI 2010). Wetland vegetation is actively controlled by local environmental authorities and a large part of the lake shores have been severely modified as a result of urban development.

Tagging and tracking. Four manatees, including three females and one male (195, 203, 285 and 180 cm in straigh-line total length) were captured momentarily and VHF transmitters (Telenax, Mexico, TX-345Y) with frequencies between 164 and 165 MHz were affixed to them. The tagging system for manatees with VHF transmitters was designed in Florida (Rathbun *et al.* 1987), where it has been used extensively (Deutsch *et al.* 2003; Reep and Bonde 2006; Gannon *et al.* 2007); furthermore, it has been used successfully in the Mexican Caribbean coasts (Castelblanco-Martínez *et al.* 2013) and in fluvio-lacustrine systems of Tabasco (Morales-López *et al.* 2012). The use of telemetry to document the behavior has also been reported for other large aquatic vertebrates such as the dugong (Sheppard *et al.* 2010). The manatees were captured and tagged by experienced personnel, following a standard protocol, with the use of 4-inch mesh-size silk purse seines (Morales-López *et al.* 2012), and under a license issued by the Mexican environmental authorities (SGPA/DGVS/01103/07). The tracking of animals was carried out between April and August 2007.

For the tracking sessions, the day was divided into three observation periods: 6:00 to 12:00 h, 12:00 to 18:00 h and

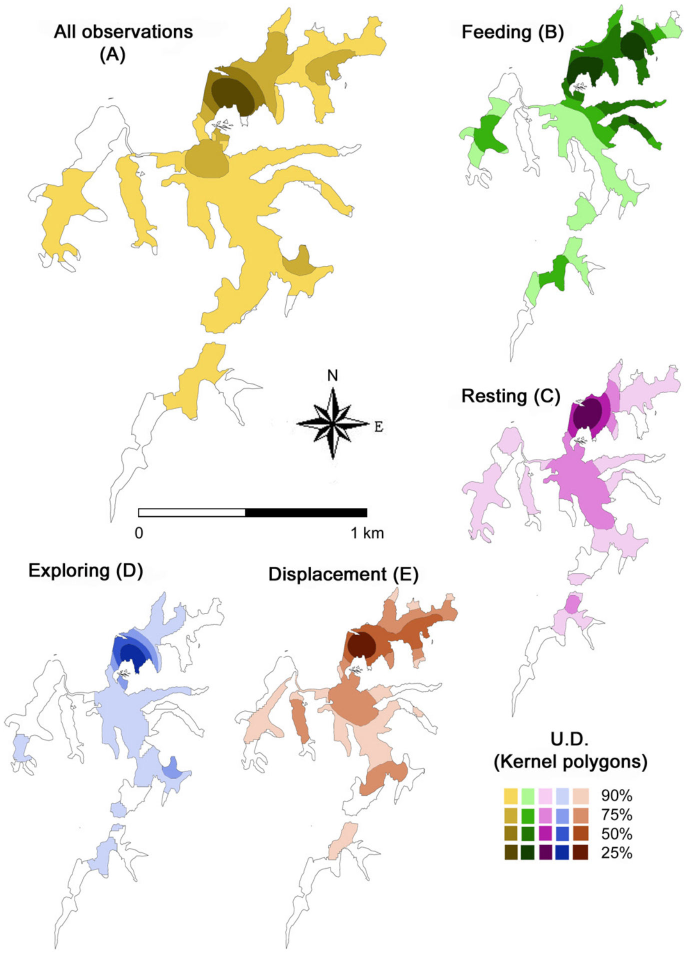

Figure 2. Utilization distribution (UD) by four manatees radio-tagged with a VHF system in Laguna de las Ilusiones, Villahermosa, Tabasco, Mexico, between April and August 2007. UD polygons were calculated by Kernel densities of the locations recorded during the study for all observations (A), and for each of the general behaviors observed (B-E).

18:00 to 0:00 h to cover the hours after sunrise and sunset. Some authors (Colmenero and Hoz 1986; Jiménez 1999; Jiménez 2002, Horikoshi-Becket and Shulte 2006) have reported that in sites with high human activity, the activity of manatees peaks in the twilight hours. The tracking of each individual and the tracking timetable were determined at random before each session. In each session, we recorded direct *ad-libitum* observations (Altmann 1974) of the general behavior exhibited by animals: feeding, resting, exploration and displacement. The position of each animal was recorded with a GPS (Garmin Etrex 10, Ltd. Kansas). Using the focal individual method, the presence of other individuals (tagged and untagged) was also recorded, along with data on the characteristics and conditions of the habitat (Hartman 1979; Axis-Arroyo *et al.* 1998; Jiménez 2005; Olivera-Gómez and Mellink 2005).

Characteristics of the Habitat: Water depth and temperature were recorded directly from a sonar unit (Humminbird 686C IF Eufala, Alabama). The distance to the nearest shore was estimated using a digital distance meter (Truepulse 200, Laser Technology, Inc., Colorado). The presence and percentage of occurrence of trees and wetland vegetation was determined within a 50 m radius from the site where the individual was located. The percentage of cloud cover was estimated visually. Rain was recorded as nil; light; short-term and heavy; and persistent heavy. Finally, the state of water was estimated according to the first four categories in the modern Beaufort scale (World Metereological Organization 2012): 0) calm water, like a mirror; 1) ripples with appearance of scales, no foam crests; 2) small wavelets, crests of glassy appearance, not breaking; 3) large wavelets, crests begin to break.

Table 1. Final Logistic Regression Models for each of four general behavior types registered in four radio-tagged manatees in Laguna de las Ilusiones, Villahermosa, Tabasco, Mexico, between April and August 2007. The best models are in bold. AICc = Akaike Information Coefficient for small samples; ΔAICc = increase in AICc.

Model	Nil Dev./Res. Dev.*	K	AICc	ΔAICc	$\exp((AIC_{min}-AIC_i)/2)$
Feeding					
Depth + distance to the shore + tree cover + wind speed	0.31	4	66.38		
Depth + distance to the shore + tree cover + wind speed + association		8	66.74	-0.357	0.836
Depth + distance to the shore + tree cover		3	72.21	-5.828	0.054
Resting					
Distance to the shore + tree cover + Association	0.89	6	271.48		
Association + tree cover		5	272.00	-0.525	0.769
Distance to the shore + tree cover + water condition + association		10	272.28	-0.807	0.668
Exploration					
Association + depth	0.97	5	310.98		
Depth + association + water condition		9	311.95	-0.969	0.615
Depth + water condition		5	312.21	-1.230	0.541
Displacement					
Depth + cloudiness + human activity	0.90	5	325.69		
Depth + human activity		4	327.07	-1.380	0.501
Depth		1	333.15	-7.460	0.024

* Null Deviance/Residual Deviance, proportion of the deviance explained by the final model

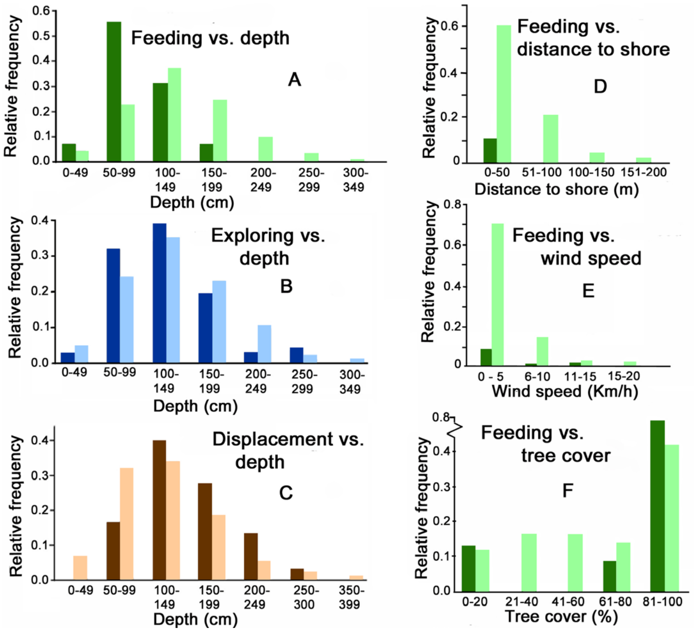

Figure 3. Distribution of the variables that were significant in the final Logistic Regression models for feeding, exploration and displacement recorded in radio-tagged manatees in this study at Laguna de las Ilusiones, Villahermosa, Tabasco, Mexico, between April and August 2007. Black bars are the number of sites where the behavior was observed, and white bars are the number of sites where the behavior was not observed.

Anthropogenic activity: This was recorded considering three categories: 1) nil, no activity; 2) medium, when there was spatial coincidence of manatees with any human activity or disturbance (for example, passing or presence of boats, fishing activities and human activities on the shore), and 3) high, when the activity leads to a reaction on the manatee, either by distancing from the human activity or by modifying its own activity.

Use of space. Polygons were built considering percent distribution levels of 25, 50, 75 and 95 %, named as utilization distribution (UD). Polygons were built with Kernel's fixed procedure (Worton 1989) in the Animal Movement extension (Hooge and Eichenlaub 1997) in Arc View 3.3 (Environmental System Research Institute, Inc., California, 2002). UD was calculated using the first position where an individual manatee was found during a tracking session. Other positions were included in the same session when more than three hours passed from the first observation, or when the animal changed its location in more than 100 m.

Usage model and habitat selection versus characteristics of the habitat. By means of a step-by-step binary logistic regression with the Program R (R Core Team 2013), considering the change that occurs with the maximum likelihood at each step as criterion to include or exclude variables in the model.

Activity and association with other individuals. Changes in activities between the selected periods of time were estimated with a Kruskal-Wallis test adjusted for ties (ZAR 1986). The mean proportion of time corresponding to each behavior observed was recorded for each sampling session. Cole´s simple association coefficient C_7 (Cole 1949) was used to explore the spatial association between tagged individuals, and between tagged individuals and other individuals in the population. C_7 values higher than 0.5 were considered as statistically significant (Bauman 1998).

Results

Manatees were tracked for a total of 174 h in the various lake environments, with an effective direct observation time of 113 h, which results in an effort/observation rate of 65 %. The time dedicated to each individual was about 30 h, except for the young male, for whom only 20 h of observation were recorded. With regard to the use of space, the 95 % Kernel polygon (home range) includes 80 % of the total lake area, while the 50 % Kernel polygon (core range) shows that manatees used only 6 % of the area during the dry season, focusing on the northern portion (Figure 2A).

The core areas (50 % Kernel polygons) of the different behaviors overlap (Figures 2C, 2D and 2E), but feeding and resting areas are more extensive and distinctive areas. Displacement entails broader and targeted movements relative to exploration, and indeed produced the most extensive core area. The feeding core area (*n* = 29 observations) was located to the north and east of the lake (Figure 2B), while resting (*n* = 55), displacement (*n* = 104) and exploration (*n* = 69) core areas are located exclusively in the northern portion of the lake.

The significant variables in the final logistic regression models are shown in Table 1. As regards feeding, four variables accounted for most of the variation: depth, distance to the shore, tree cover and wind speed. The resting behavior was partially explained by the presence of other individuals (company) and tree cover. Exploration was best modeled using depth, distance to the shore and company. Finally, for displacement, the variables in the best model included depth, cloudiness and human activities.

The distribution of observations for the variables in the best model is shown in Figures 3 and 4). Depth is a key variable, because it occurs in the best models for three of the four behaviors evaluated; feeding was observed in shallower areas compared to exploration or displacement (0.5 to 1.5 m depth; Figures 3A, 3B and 3C). Feeding was affected to a lesser extent by distance to the shore or wind speed (Figures 3D and 3E). The manatees observed fed more frequently in areas with high tree cover (Figure 3F).

The resting behavior was negatively associated with company (Figure 4A), and was recorded mainly in areas of intermediate tree cover, avoiding areas that were either

Table 2. Association (Cole Index C_7) between radio-tagged manatees (between them and with other non-tagged individuals) in Laguna de las Ilusiones, Villahermosa, Tabasco, Mexico between April and August 2007.

Individual	Male 180 cm	Female 203 cm	Female 195 cm	Female 285 cm
Female 203 cm	0			
Female 195 cm	0.020	0.064		
Female 285 cm	0	0.440	0	
Other individuals	0.528	0.208	0.019	0.130

open (Figure 4B) or close to the the shore (4C). With respect to displacement movements, a positive association with low cloud cover (Figure 4D) and low human activity (Figure 4E) was noted; displacement also occurs in sites of intermediate depth (Figure 3C). Exploration is the most frequent behavior at intermediate depths (50 to 199 cm, Figure 3B), and when animals were accompanied by other manatees (Figure 4F).

The distribution of records (median, interquartile interval, and UD interval) for each general activity with regard to the three periods of time in the study was as follows: the resting behavior differs between the three observation periods (H = 6.68, *P* = 0.035). Animals rested less between 18:00 and 00:00 h. Exploration was not significantly different between observation periods (H = 1.55, *P* = 0.461). Displacement took place mainly in the morning period (H = 7.55, *P* = 0.023), and decreased in the afternoon. Feeding showed the opposite trend, occurring primarily in the afternoon (H = 9.85, *P* = 0.007). Avoidance of boats and other human activities were recorded occasionally, with no differences between observation periods (H = 2.73, *P* = 0.420).

The manatees tracked were accompanied by at least one other individual for 53 % of the observation time. The only statistical association occurred between the young male and other non-tagged individuals (C_7 = 0.58, Table 2). The 203 and 285 cm long females were frequently together, but the association between them was not significant (C_7 = 0.44) as per Bauman (1998). The 195 cm long female was the most independent manatee.

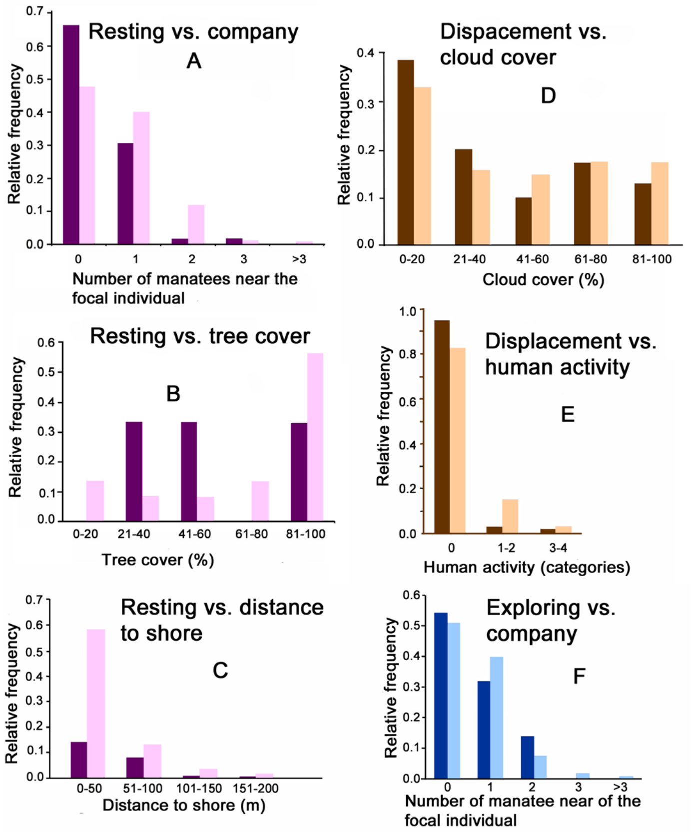

Figure 4. Distribution of the variables that were significant in the final Logistic Regression models for resting, exploration and displacement recorded in radio-tagged manatees in this study at Laguna de las Ilusiones, Villahermosa, Tabasco, Mexico, between April and August 2007. Black bars are the number of sites where the behaviour was observed, and white bars are the number of sites where the behavior was not observed.

Discussion

Aerial surveys and other methods used for the detection, counting and recording the behavior of manatees are impractical; as a result, details on the biology and ecology of the species in these ecosystems are little known (Marsh *et al.* 2012). The characteristics of the habitat in Laguna de las Ilusiones change as water level increases with the advent of the rainy season. Under the dry conditions that prevailed throughout the study, the perennial wetland vegetation (the major food source for manatees in the lake) occurred in just 14 % of its shores. There are mango trees in 48 % of the lake margins, and the dry season coincided with the availability of mango fruits. The 2007 dry season showed an atypical duration in the region, spanning until early September; consequently, manatee behavior was recorded under unusually dry conditions. The results obtained indicate that manatees occur in almost the entire lake, with their core areas (50 % Kernel polygons; Storline 2006; Roux and Bernard 2007) located in the northern portion of the lake. This area includes an arm of the lake connected with the central area by a narrow canal approximately 50 m wide that was very shallow, displaying a depth of less than 50 cm throughout the study. These conditions restrict the movements of manatees in or out of the northern area, as manatees avoid depths of less than 50 cm (Hartman 1979).

Previous studies recorded more sightings in the northwest area of the lake, a zone with less boat traffic, less activity on the lake shores and a broader plant cover (Pablo-Rodríguez and Olivera-Gómez 2012). These findings contrast with ours, partly due to the difference in the method used, but also because the depth near the shore in that area was approximately 0.3 m and manatees could not easily reach the vegetation. It has been recorded that manatees are able to feed in areas where the depth is at least 0.5 m (Hartman 1979).

The northern area of the lake has more mango trees and it is where manatees have been observed feeding more frequently. This contributes to explain why manatee activities were concentrated in this area. The presence, time spent and movements of mantees are often associated with food availability (Montgomery *et al.* 1981; Jiménez 2005). In addition, this area shows little movement of boats, so that the avoidance of stress caused by a high rate of encounters with humans may have made tagged animals choose this area.

In this study, it was observed that the areas of general activity overlapped spatially, as these activities did not take place in different sites. This supports the idea that factors such as low depths at the entrance to the northern area of the lake probably restricted the movements of manatees in some areas. However, individuals were occasionally located in other areas, returning to the northeast area a few days

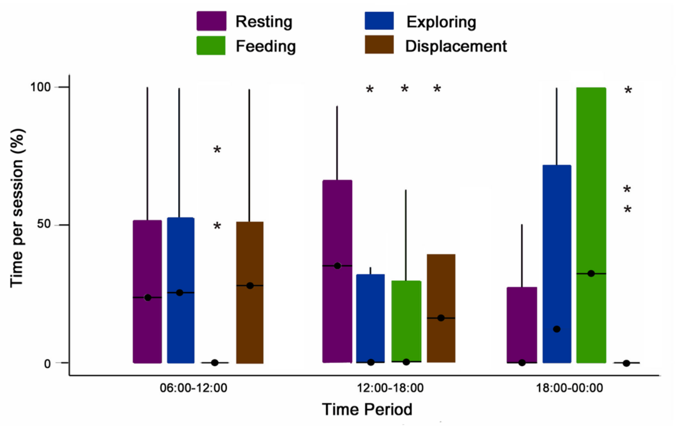

Figure 5. Distribution (median, interquartile range and range, * = extreme data) of the general activities analyzed in the study, carried out by radio-tagged manatees in Laguna de las Ilusiones, Tabasco, Mexico, from April to August 2007.

later. Manatees may also have concentrated their activities within the same area to minimize the energy expenditure associated with displacement.

Manatees showed frequent movements in shallow waters along the lake shores, swimming through the deepest central area to go directly to other shores, as recorded in Florida (Hartman 1979). Manatees spent time in specific areas, making slow movements associated with exploration, resting or feeding. Exploration and displacement were the behaviors observed most frequently in the study, as reported by Pablo-Rodríguez and Olivera-Gómez (2012). In this sense, Bailey *et al.* (1996) point out that, in general, when food is scarce and sparse, large herbivores spend more time moving across patches, instead of staying in a single patch. *Dugong dugon* actively avoids feeding in a single patch of vegetation and moves randomly to other patches, abandoning the feeding patches; this behavior results in a faster recovery of the vegetation after disturbance (Preen 1993), so that exploration and displacement are frequent activities.

Our logistic regression model shows that depth, tree cover, company and distance from the shore explain the greatest portion of the variance. In this study, manatees used less deep areas for feeding than for performing another activity (Figure 3A). Wetland vegetation is more abundant in shallow gentle-sloping shores, although manatees that avoid shallow areas can feed in deep waters, where the slope allows them to move quickly toward deeper areas (Hartman 1979, Olivera-Gómez and Mellink 2005). In the case of the tree cover, trees provide shade, in addition to leaves, flowers and fruits that are usually consumed (O'Shea 1986). Forested patches in urbanized areas are associated with the shore vegetation and other plants, which would explain the importance of this variable in the feeding model. In the necropsy of one female (2005), large amounts of mango seeds were found throughout the digestive tract (Olivera-Gómez, pers. obs.). This seasonal focus on specific resources has also been reported elsewhere (Hartman 1979; Montgomery *et al.* 1981).

The logistic regression model showed a poor goodness of fit for the resting, exploration and displacement behaviors (Table 1). During these activities, manatees behave with relative independence of the characteristics of the habitat, as reported by Hartman (1979) and Reynolds (1981). On the other hand, there may be other variables that were not taken into account and which could help to explain the occurrence of these activities.

This study showed a significant effect of the time of the day on displacement, resting and feeding. Manatees showed the displacement behavior mostly during the morning and decreased this activity in the afternoon, as they were more sedentary and spent more time feeding. The resting behavior also increased during the afternoon. Manatees have been described as arrhythmic (Hartman 1979; Reynolds, 1981), although in areas with marked human activity, they seem to be more active at dawn, dusk and during nighttime (Colmenero and Hoz 1986; Jiménez 1999; Jiménez 2002; Horikoshi-Becket and Shulte 2006). While studying animals in captivity, Holguin *et al.* (2015) found a circadian cycle of the resting behavior, with manatees being more active during the day, which is consistent with other studies of manatees in captivity (Hénaut *et al.* 2010, Kikuchi *et al.* 2010).

The main source of food in the lake is the vegetation on the shores; furthermore, manatees might avoid feeding on grasses during the hours of high temperature to avoid problems associated related to post-gastric digestion (Reynolds and Rommel 1996). Instead, manatees may search for fresher materials such as fruits or leaves that are submerged, as was ocassionally observed. This study found that during almost half the observation time, animals were accompanied by at least one other individual. Hartman (1979) and Reynolds (1981) observed that manatees tend to be associated with one another when using a particular resource — food, in this case — and move apart afterwards, a behavior that Reynolds (1981) described as social facilitation.

Implications for conservation. The behavior of manatees was influenced by seasonal conditions and human activities. The latter may exert not only a direct influence, but also through the modification of the habitat, as by clearing wetland vegetation. Recreational vessels, the management of floating plants and patrolling in response to illegal fishing and filling has increased. Rapid motor vessels are also a potential threat for manatees in this shallow lake, especially when animals gather together due to occasional restrictions, as in the case of this study. On several occasions we noted that manatees did not react to vessels that passed near them. In thermal shelters located in Florida, manatees have become adapted to the presence of vessels, but modify their distribution range by increasingly occupying areas restricted to vessels (Buckingham *et al.* 1999).

If the plant cover in the lake is reduced by urbanization, there will be a noticeable effect on manatees, especially under atypical conditions such as those observed in the study, which makes the conservation of the lake shores a top priority. The northwest area of the lake has a margin with an extensive plant cover; perhaps the depth could be increased in this area through dredging. An intensive management of the lake, its shores and its users should be undertaken, to develop strategies that contribute to ensure environmental conditions suitable for manatees.

Acknowledgments

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Literature cited

Altmann, J. 1974. Observational study of behavior: sampling methods. Behaviour 49:227-265.

Axis-Arroyo, J., B. Morales-Vela, D. Torruco-Gómez, and M. E. Vega-Cendejas. 1998. Variables asociadas con el uso de hábitat del manatí del Caribe (*Trichechus manatus*), en Quintana Roo, México (Mammalia). Revista de Biología Tropical 46:791-803.

Bailey, D. W., J. E. Gross, E. A. Laca, L. R. Rittenhouse, M. B. Coughenour, D. M. Swift, and P. L. Sims. 1996. Mechanisms that result in large herbivore grazing distribution patterns. Journal of Range Management 49:386-400.

Bauman, P. J. 1998. The Wind Cave National Park elk herd: home ranges, seasonal movements, and alternative control methods. M. S. Thesis. South Dakota State University. Brookings, U. S. A.

Buckingham, C. A., L. W. Lefebvre, J. M. Schaefer, and H. I. Kochman. 1999. Manatee response to boating activity in a thermal refuge. Wildlife Society Bulletin 27:514-522.

Castelblanco-Martínez, D. N., J. Padilla-Sáldivar, H. A. Hernández-Arana, D. Slone, J. P. Reid, and B. Morales-Vela. 2013. Movement patterns of Antillean manatees in Chetumal Bay (Mexico) and coastal Belize: A challenge for regional conservation. Marine Mammal Science 29:166-182.

Cole, L. C. 1949. The measurement of interspecific association. Ecology 30:411-424.

Colmenero, R. C., and E. Z. Hoz. 1986. Distribución de los manatíes, situación y su conservación en México. Anales del Instituto de Biología, UNAM. México, Serie Zoología 56:955-1020.

CONANP. 2010. Programa de Acción para la Conservación de la Especie: Manatí (*Trichechus manatus manatus*). Compilado por Olivera Gómez, L. D., A. Ortega-Argueta, B. Morales Vela, and L. C. Colmenero Rolón. Comisión Nacional de Áreas Naturales Protegidas, SEMARNAT. Ciudad de México, México.

Deutsch, C. J., J. P. Reid, R. K. Bonde, D. E. Easton, H. I. Kochman, and T. J. O'Shea. 2003. Seasonal movements, migratory behavior, and site fidelity of West Indian manatees along the Atlantic coast of the United States. Wildlife Monographs 151:1-77.

Estrada-Loreto, F., E. Barba-Macías, and R. Ramos-Reyes. 2013 Cobertura temporal de los humedales en la cuenca del Usumacinta, Balancán, Tabasco, México. Universidad y Ciencia 29:141-151.

Gannon, J., K. M. Scolardi, J. E. Reynolds III, J. K. Koelsch, and T. J. Kessenich. 2007. Habitat selection by manatees in Sarasota Bay, Florida. Marine Mammal Science 23:133-143.

Hartman, D. S. 1979. Ecology and Behavior of the Manatee (*Trichechus manatus*) in Florida. American Society of Mammalogist, Special Publication No. 5. Lawrence, Kansas.

Hénaut, Y., S. P. Becerra-López, s. Machkour-M´rabet, B. Morales-Vela, P. Winterton, and F. Delfour. 2010. Activities and social interactions in captive Antillean manatees in México. Mammalia 74:141–146.

Holguín-Medina, V. E., J. Fontenele-Araujo, V. M. Alcaraz-Romero, J. F. Cortes, and J. Muñoz-Delgado. 2015. Circadian and ultradian activity rhythms in manatee (*Trichechus manatus manatus*) in captivity. Biological Rhythm Research 46:631-645.

Hooge, P. N., and B. Eichenlaub. 1997. Animal movement extensions to Arcview, Version 2.0 Alaska Science Center-Biological Science Office, U.S. Geological Survey. Anchorage, U. S. A.

Horikoshi-Beckett, C., and B. A. Schulte. 2006. Activity patterns and spatial use of facility by group of captive female manatees (*Trichechus manatus latirostris*). Zoo Biology 25:285-301.

INEGI. 2010. Censo de Población y Vivienda. Disponible en: http://www3.inegi.org.mx/sistemas/mexicocifras/default.aspx?e = 27. Consulted: January 19, 2016.

Jiménez, I. 1999. Estado de conservación, ecología y conocimiento popular del manatí (*Trichechus manatus*) en Costa Rica. Vida Silvestre Neotropical. 8:18–30.

Jiménez, I. 2002. Heavy poaching in prime habitat: the conservation status of the West Indian manatee in Nicaragua. Oryx. 36:272–278.

Jiménez, I. 2005. Development of predictive models to explain the distribution of the West Indian manatee *Trichechus manatus* in tropical watercourses. Biological Conservation 125:491-503.

Kikuchi, M., V. M. F. Da Silva, F. C. Rosas, and N. Miyazaki. 2010. Application of acceleration data loggers to classify the behavior of captive Amazonian manatees (*Trichechus inunguis*). Coastal Marine Science. 34:24–30.

Koelsch, J. 1997. The seasonal occurrence and ecology of Florida manatees (*Trichechus manatus latirostris*) in coastal waters near Sarasota, Florida. Master Thesis, University of South Florida. Sarasota, U. S. A.

Lefebvre, L. W., J. P. Reid, G. B. Rathbun, and D. P. Domning. 2001. Status and biogeography of the West Indian manatee. Pp. 425-474 in Biogeography of the West Indies: new patterns and perspectives. (Woods, C. A., and F. E. Sergile, eds.). CRC Press. Boca Raton, U. S. A.

Marsh, H., T. J. Oshea, and J. E. Reynolds III. 2012. Ecology and Conservation of the Sirenia, Dugongs and Manatees. Cambridge University Press. New York, U. S. A.

Montgomery, G. G., R. C. Best, and M. Yamakoshi. 1981. A radio-tracking study of the Amazonian Manatee *Trichechus inunguis* (Mammalia:Sirenia). Biotropica 13:81-85.

Morales-López, M., L. D. Olivera-Gómez, and C. E. Zenteno-Ruiz. 2012. Intervalo respiratorio y desplazamientos de manatíes Antillanos *Trichechus manatus manatus* (Sirenia). Comparación entre las temporadas seca y lluviosa en una laguna aislada. Mastozoologia Neotropical 19:117-126.

Olivera-Gómez, L. D., and E. Mellink. 2005. Distribution of the Antillean manatee (*Trichechus manatus manatus*) as a function of habitat characteristics, in Bahía de Chetumal, México. Biological. Conservation 121:127-133.

O´Shea, T. J. 1986. Mast foraging by West Indian manatee (*Trichechus manatus*). Journal of Mammalogy 67:183-185.

Pablo-Rodríguez, N., and L. D. Olivera-Gómez. 2012. Situación de una población aislada de manatíes *Trichechus manatus* (Mammalia: Sirenia: Trichechidae) y conocimiento de la gente, en una laguna urbana, en Tabasco, México. Universidad y Ciencia 28:15–26.

Pérez-Garduza, F. 2013. Evaluación de la eficiencia de cuatro técnicas para determinar la abundancia de manatíes *Trichechus manatus* en ambientes poco visibles. Tesis de Maestría. Universidad Juárez Autónoma de Tabasco. Villahermosa, México.

Preen, A. R. 1993. Interactions between dugongs and seagrasses in a subtropical environment. Ph. D. Dissertation, James Cook University. Townsville, Australia.

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Disponible en: http://www.R-project.org/. http://www.r-project.org. Consulted: March 17, 2015.

Rathbun, G. B., J. P. Reid, and J. Bourassa. 1987. Design and construction of a tethered, floating radio tag assembly for manatees. Report prepared by U. S. Fish and Wildlife Service, Denver Wildlife Research Center, Gainesville Field Station. NTIS Doc. No. PB87-161345. Avalilable at: leon_olivera@yahoo.com.mx

Reep, R. L. and R. K. Bonde. 2006. The Florida Manatee, Biology and Conservation. University Press of Florida. Gainesville, U. S. A.

Reynolds, J. E. III. 1981. Aspects of the social behavior and herd structure of a semi-isolated colony of West Indian manatees, *Trichechus manatus.* Mammalia 45:431-451.

Reynolds, J. E., and S. A. Rommel. 1996. Structure and function of the gastrointestinal tract of the Florida Manatee, *Trichechus manatus latirostris*. Anatomical Records 245:539-558.

Roux, C., and R. T. F. Bernard. 2007. Home range size, spatial distribution, and habitat use of elephants in two enclosed game reserves in the Eastern Cape Province, South Africa. African Journal of Ecology 47:146-153.

Self-Sullivan, C., and A. Mignucci-Giannoni. 2008. *Trichechus manatus* ssp. *manatus*. En: IUCN (2011) IUCN Red List of Threatened Species Versión 2011.2. Disponible en: http://www.iucnredlist.org. Consulted: March 7, 2016.

Sheppard, J. K., H. Marsh, R. E. Jhones, and I. R. Lawler. 2010. Dugong habitat use in relation to seagrass nutrients, tides and diel cycles. Marine Mammal Science 26:855-879.

Smith-Cavros, E. M., S. Duluc-Silva, M. C. Rodriguez, P. Ortiz, and E. O. Keith. 2012. You can’t eat money when you are hungry”: campesinos, manatee hunting, and environmental regret in Veracruz, Mexico. The Journal of Culture and Agriculture 34:68-80.

Storline, J. T. 2006. Movements and habitat use of female Roosevelt elk in relation to human disturbance on the Hoko and Dickey game management units, Washington. Master Thesis. Faculty of Biology, Humboldt State University. Arcata, U. S. A.

World Meteorological Organization. 2012. Manual on Marine Meteorological Services. Volume I. WMO-No. 558. Geneva, Switzerland.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.

Zar, J. H. 1986. Biostatistical Analysis, Second Edition. Prince-Hall International. Englewood Cliffs, U. S. A.

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Notes on the taxonomy of mountain viscachas of the genus *Lagidium* Meyen 1833 (Rodentia: Chinchillidae)

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Mountain viscachas of the genus *Lagidium* Meyen 1833 are medium-to-large hystricomorph rodents (1.5 -- 3 kg) that live in rocky outcrops from Ecuador to southern Argentina and Chile. *Lagidium* includes more than 20 nominal forms, most of them based on one or two individuals, which were first described during the 18th and 20th. Subsequent revisions reduced the number of species to three to four, depending upon the author. Within the genus, *Lagidium viscacia* (Molina, 1782) is the most widely distributed species, with populations apparently extended from western Bolivia to southern Argentina and Chile. We reviewed > 100 individuals of *Lagidium*, including skins and skulls, most of them collected in Argentina. We performed multivariate statistical analysis (*i. e.,* principal component analysis [PCA], discriminant analysis [DA]) on a subset of 55 adult individuals grouped according to their geographical origin, using 16 skull and tooth measurements. In addition, we searched for differences in cranial anatomy across populations. PCA and DA indicate a moderate overlap between individuals from southern Argentina, on one hand, and northwestern Argentina, western Bolivia and northern Chile, on the other. The external coloration, although variable, showed a predominance of gray shades in southern Argentina and yellowish gray in northwestern Argentina. Specimens of southern Argentina were characterized by their bigger overall size, nasals expanded in its front half, and narrow dorsal root of the zygomatic process of the maxillary, while those of northwestern Argentina were smaller, with nasals lacking expansions and the dorsal root of the zygomatic process of the maxillary broad. Our study provides coincident results from quantitative and qualitative morphology that allow us to clearly differentiate southern Argentinean populations of *Lagidium viscacia* from those of northwestern Argentina and western Bolivia. The oldest available name for the populations from southern Argentina, sometimes referred as *L. boxi*, is *moreni*, a taxon with an unclear type locality. The status of the populations from northwestern Argentina and western Bolivia is relatively more complex, since at least eight nominal forms were described from this general area and because our sampling is far from being extensive. In addition, is also unclear if these populations correspond to one or more species, as well as their degree of differentiation from *L. viscacia* s. s. Without analyzing topotypes of all nominal forms and adequate samples across the entire distribution range, it is premature to put forward a formal taxonomic proposal; as such, at this moment we prefer to maintain those populations from northwestern Argentina, western Bolivia and central Chile under *L. viscacia*.

El género *Lagidium* Meyen 1833 incluye más de 20 formas nominales, la mayoría de ellas basadas en uno o dos ejemplares, descriptas entre finales del siglo XVIII y principios del XX. Revisiones posteriores redujeron este número a tres o cuatro especies, dependiendo del autor. Más recientemente, el uso de técnicas moleculares ha demostrado que esos números tampoco son representativos de la diversidad real de este género. *Lagidium viscacia* (Molina 1782) es un taxón ampliamente distribuido, con poblaciones desde el oeste de Bolivia hasta el sur de Argentina y Chile. Sin embargo, su variación morfológica y geográfica no ha sido evaluada con metodologías modernas y series extensas de ejemplares. En este trabajo se revisaron > 100 individuos, incluyendo pieles y cráneos colectados principalmente en Argentina. Se realizaron análisis multivariados (*i. e.,* análisis de componentes principales, discriminantes) sobre un subconjunto de 55 ejemplares adultos agrupados según su procedencia geográfica y a partir de 16 medidas cráneo-dentarias. En los análisis de componentes principales y discriminantes se registró una superposición moderada entre individuos de distintas localidades del sur de Argentina por un lado y del noroeste de Argentina, oeste de Bolivia y norte de Chile por el otro. La coloración externa, a pesar de ser muy variable, mostró una predominancia de tonos grises hacia el sur de Argentina y amarillentos hacia el noroeste. Los especímenes del sur de Argentina, aquí referidos como *L. moreni*, se distinguieron por su mayor tamaño general, sus nasales más anchos y expandidos en su mitad anterior y por tener la raíz dorsal del proceso cigomático del maxilar angosta. Por el contrario, los ejemplares del noroeste de Argentina, que aquí optamos por mantener dentro del concepto de *L. viscacia*, poseen un menor tamaño general, los nasales angostos y sin expansiones y la raíz dorsal del proceso cigomático del maxilar ancha.

Key words: Caviomorpha; Chinchilloidea; Hystricomorpha: taxonomy.

Introduction

Mountain viscachas of the genus *Lagidium* Meyen 1833 (Rodentia, Chinchillidae) are medium-to-large hystricomorph rodents (1.5 to 3 kg) that live in rocky outcrops from Ecuador to southern Argentina and Chile (Spotorno and Patton 2015). The taxonomic history of this genus, similar to other Neotropical mammals, can be divided into three main stages. During the first period, that spans between the late 18th century and the early 20th century, more than 20 nominal forms were described, mostly based on one or two specimens from their respective type localities (*e. g.*, Thomas 1907). At the second stage, under the paradigm of the biological species concept, most of these names were regarded as synonyms, depending upon the author (some of them recognized as subspecies), of three to four more widely distributed species (*e. g.*, Cabrera 1961). Finally, the use of molecular markers in recent years suggested that this scenario is not representative of the real taxonomic diversity within the genus (Spotorno *et al.* 2004, Ledesma *et al.* 2009).

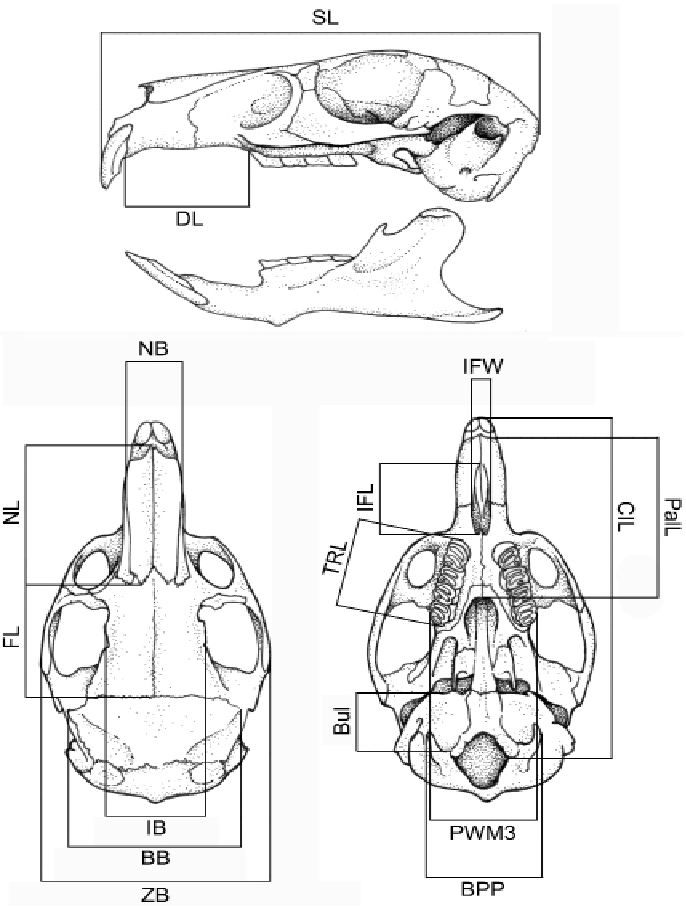

Figure 1. Measurements used in the multivariate analysis. For measurement abbreviations: see the section Materials and Methods.

Hayman (in Ellerman 1940:230-231), based on the specimens housed at the British Museum, was the first reviewer of the genus *Lagidium*. This author recognizes four species, from north to south: *L. peruanum* Meyen 1833, *L. viscacia* (Molina 1782), *L. boxi* Thomas 1921, and *L. wolfsohni* (Thomas 1907). Hayman (in Ellerman 1940) used size, presence of dorsal stripes and coloration pattern as the main diagnostic features for delimiting the different species. Subsequent authors subsumed *boxi* (*e. g.,* Cabrera 1961) and *peruanum* (*e. g.,* Spotorno and Patton 2015; but see Ledesma *et al.* 2009) under *L. viscacia*. Overall, the profusion of names within this genus was reflected by the recognition of multiple subspecies, especially within *viscacia* (*e. g.,* Cabrera 1961; Crespo 1963; Mann 1978). More recently, Spotorno *et al.* (2004) and Ledesma *et al.* (2009), combining molecular and morphometric evidences in the context of the description of a new species from Ecuador (*L. ahuacaense*), recognized several molecular lineages within *Lagidium* that partially coincide with the groups recovered in their multivariate analysis of metrical data. In addition, Ledesma *et al.* (2009) found that *L. viscacia*, as currently conceived, was not resolved as a monophyletic group. Recently, Spotorno and Patton (2015), in a conservative approach, recognized only three species (*L. ahuacaense*, *L. viscacia,* and *L. wolffsohni*) and discussed extensively the taxonomic history of the genus (see Table 1 for a synthesis of the main taxonomic hypothesis within *Lagidium*). Taxonomic uncertainties within *Lagidium* are related to the deficient definition of some taxa, the apparently limited morphological differentiation between species, and the poor representation of specimens in biological collections (Spotorno and Patton 2015).

In this work we studied, from a qualitative and quantitative approach, Argentinean and Bolivian populations referred to *L. viscacia*, in order to better understand their geographic morphological variation pattern. Based on our results, we consider that taxonomic changes are needed.

Materials and Methods

One hundred and fifty specimens referred to as *Lagidium viscacia* from Argentina and western Bolivia were examined in this study (see Appendix 1). For comparative purposes, we also included six specimens of *L. peruanum* from northern Chile. Sixteen craniodental variables were measured in adult specimens (*n* = 55) in order to quantitatively describe the size and shape of the major skull structures, as follows (Figure 1): skull length (SL), condylo-incisive length (CIL), zygomatic breadth (ZB), braincase breadth (BB), palatilar length (PalL), incisive foramina length (IFL), incisive foramina width (IFW), diastema length (DL), maxillary toothrow length (alveolar) (TRL), palatal width at M3 (PWM3), breadth across paraoccipital process (BPP), nasal length (NL), nasal width (NW), interorbital breadth (IB), frontal length (FL), and bullar length (BuL). All measurements were obtained with digital calipers to the nearest 0.05 mm, and were log-transformed before the multivariate statistical analyses.

Geographic trends and the degree of differentiation between samples were examined by multivariate statistical procedures, including principal component analysis (PCA) and canonical variate discriminant analysis (DA). Small samples from different localities were grouped following the geographic proximity criterion (*e. g.,* Musser 1968) and the similarity between the geomorphological characteristics of the localities sampled (*e. g.,* mountain slopes, relief; see Chiquito *et al.* 2014). Samples with only one individual were not included in DA. Samples were labeled in the figures and tables using the following abbreviations: **Argentina**: CH = Chubut Province, JU = Jujuy Province, LR = La Rioja Province, ME = Mendoza Province, NQ = Neuquén Province, RN = western Río Negro Province, SA = Salta Province, SJ = San Juan Province, SO = Somuncurá, TU = Tucumán Province. **Bolivia**: BO = western Bolivia. **Chile**: PE = Northern Chile (Figure 2C). The sample from RN includes two topotypes of *L. boxi* Thomas 1921, and the sample from SO includes the type series of *L. v. somuncurensis* Crespo 1963. Previous studies on *Lagidium* have shown that differences between sexes are not significant (cf. Pearson 1948); consequently, we pooled males and females in the multivariate analyses.

The variation in cranial and external qualitative anatomical characters was also documented. The anatomical terminology used to describe skull structures follows Cherem and Ferigolo (2012). Pelage coloration was assessed by side-by-side comparisons of specimens.

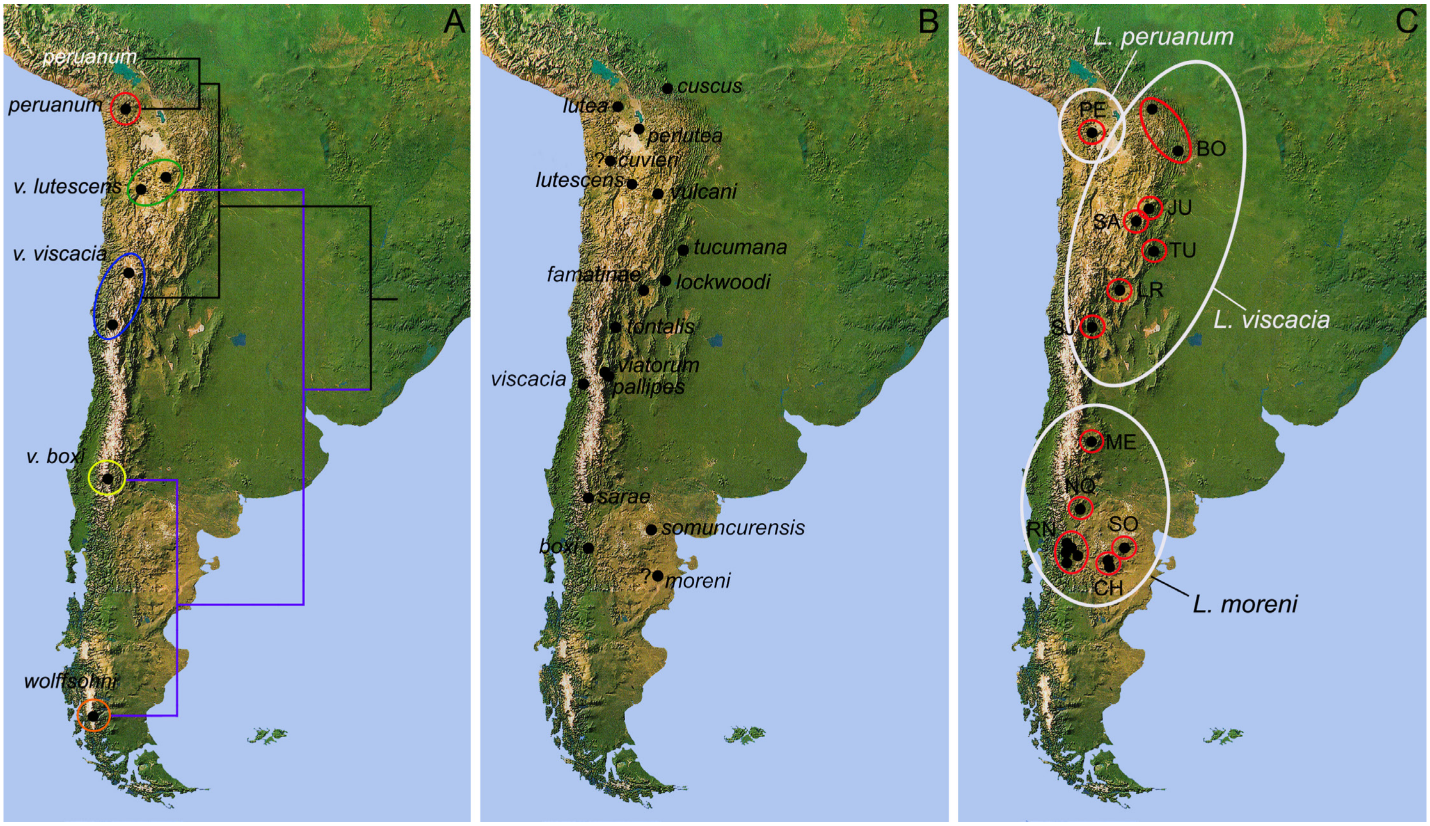

Figure 2. Map of southern South America depicting: A) A simplified tree of the phylogenetic hypothesis for *Lagidium* based on *cytb* sequences presented by Ledesma *et al.* (2009). B) Type localities of the nominal forms included by Spotorno and Patton (2015) within the synonymy of *Lagidium viscacia* (*e. g.*, Cabrera 1961; Mann 1978; Anderson 1997; the nominal forms *L. crassidens* Philippi 1896 and *L. crinigerum* Phillipi 1896, included by Osgood 1943 under the synonymy of *L. v. viscacia*, were not mapped due to uncertainties about their type localities. C) Geographic samples defined in this work (see Materials and Methods for abbreviations). White ellipses illustrate the taxonomic hypothesis proposed in this work.

Results

The principal component analysis revealed two major morphometric groups spanning along the 1st and 2nd principal components, which accounted for ~70 % of the variance (Figure 3, Table 2). All craniometric characters were positively correlated with PC1, indicating size variation as the main source of differentiation between samples (Figure 3, Table 2). The first group was composed of specimens from southern Argentina (*i. e.*, CH, NQ, RN and SO), while the second encompassed animals from northwestern Argentina (*i. e.*, JU, LR, SA, SJ, TU) and western Bolivia (BO) plus *L. peruanum* from northern Chile (PE). This latter sample (PE) appeared as the smallest in cranial size within this second group. Overall, the overlap in multivariate

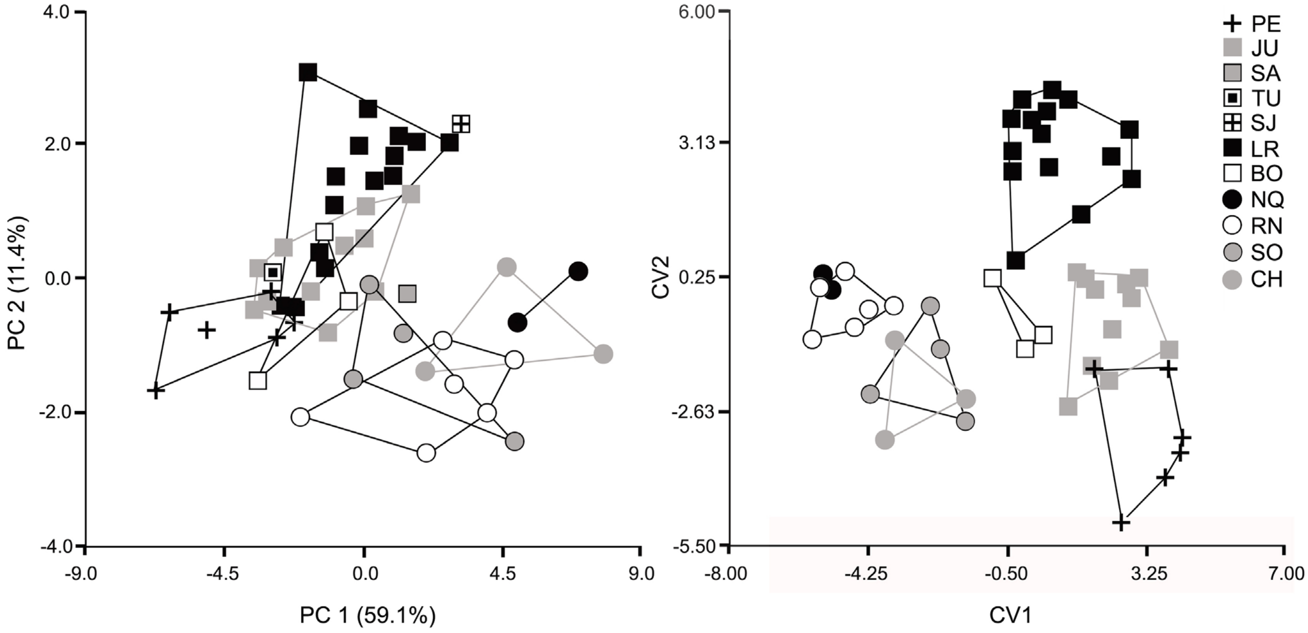

Figure 3. Specimen scores of adult individuals of *Lagidium* (*n* = 55) for Principal Components 1 and 2 (left), and for Canonical Variates 1 and 2 extracted from an eight-group discriminant function analysis (right). See Materials and Methods for the explanation of the abbreviations.

Table 1. Main taxonomic hypothesis for the species of the genus *Lagidium* (Rodentia, Chinchillidae), including the arrangement of subspecies proposed by different authors.

Hayman (in Ellerman 1940)	Cabrera (1961)	Woods and Kilpatrick (2005)	Spotorno and Patton (2015)
Lagidium peruanum	***Lagidium peruanum***	***Lagidium peruanum***	Included within ***L. viscacia***
L. p. peruanum	*L. p. peruanum*	*L. p. peruanum*	
L. p. arequipe		*L. p. arequipe*	
L. p. inca	*L. p. inca*	*L. p. inca*	
L. p. pallipes		*L. p. pallipes*	
L. p. punensis		*L. p. punensis*	
L. p. saturata	*L. p. saturatum*	*L. p. saturata*	
L. p. subrosea	*L. p. subroseum*	*L. p. subrosea*	
Lagidium viscacia	***Lagidium viscacia***	***Lagidium viscacia***	***L. viscacia***
L. v. viscacia	*L. v. viscacia*	*L. v. viscacia*	
	L. v. boxi	*L. v. boxi*	
L. v. cuscus	*L. v. cuscus*	*L. v. cuscus*	
	L. v. cuvieri	*L. v. cuvieri*	
L. v. famatinae	*L. v. famatinae*	*L. v. famatinae*	
L. v. lockwoodi	*L. v. lockwoodi*	*L. v. lockwoodi*	
L. v. lutea			
L. v. moreni	*L. v. moreni*	*L. v. moreni*	
	L. v. pallipes		
L. v. perlutea		*L. v. perlutea*	
	L. v. sarae	*L. v. sarae*	
L. v. tontalis		*L. v. tontalis*	
L. v. tucumana	*L. v. tucumanum*	*L. v. tucumana*	
L. v. viatorum		*L. v. viatorum*	
L. v. vulcani	*L. v. vulcani*	*L. v. vulcani*	
L. boxi			Included within ***L. viscacia***
L. b. boxi			
L. b. sarae			
Lagidium wolffsohni		***Lagidium wolffsohni***	***Lagidium wolffsohni*** ***Lagidium ahuacaense***

space among geographic samples within the first and second groups was moderate to high (Figure 3).

The discriminant analysis correctly allocated almost all specimens in their respective geographic sample (Table 3). The 1st and 2nd canonical variates accounted for ~80 % of the variance. Specimens from southern Argentina (*i. e.*, CH, NQ, RN and SO) differed from the other samples by having overall larger and more robust crania, with markedly larger characters related to BB, BPP, PalL, and NW (Figure 3, Table 2 and 3).

Among the Argentinean samples, the two main groups identified through PCA can be diagnosed based on the distribution of qualitative characters. The external coloration was relatively variable among samples, a fact previously noted by Pearson (1948). However, there is a clear predominance of grayish-colored specimens, with well-marked and usually broad dorsal stripes among southern (CH, RN, SO; Figure 4A) and west-central (ME) Argentinean samples and yellowish-gray individuals (more or less suffused with orange), with diffuse to well-marked, usually narrow, dorsal stripes among the populations from northwestern Argentina (JU, LR, SA, TU; Table 4; Figure 4B). Individuals from NQ were metrically nested within samples from southern Argentina, although their external coloration was mostly yellowish-gray. A main difference between both groups was the shape of nasals, which were relatively large with a conspicuous widening in the distal half in specimens from southern Argentina (*i. e.*, CH, NQ, RN and SO), and narrow with nearly straight and parallel borders in the remaining samples (*i. e.*, JU, LR, SA, SJ, TU; Figure 5). In addition, the dorsal root of the zygomatic process of the maxilla was narrow in the first group and broad in the second (Figure 5).

Samples from BO and PE have a similar cranial architecture relative to specimens from northwestern Argentina, differing slightly from them in the quantitative characters.

Discussion

The present study provides mostly coincident results from quantitative and qualitative morphological traits, which allow differentiating the southern Argentinean samples of *Lagidium viscacia* from those of northwestern Argentina, as well as separating both from *L. peruanum* (Figure 2C). The magnitude of these differences stands at the species level (cf. Ledesma *et al.* 2009; Spotorno and Patton 2015); the question that remains, however, regards the proper allocation of names to the southern and northwestern Argentinean forms.

Specimens from west-central (ME) and southern Argentina are characterized by grayish colorations (CH, RN, SO; except NQ which is yellowish gray), with well- marked and usually broad dorsal stripes, nasals expanded anteriorly and narrow dorsal roots of the zygomatic process of the maxilla. Four nominal taxa traditionally linked with *viscacia* were described from southern Argentina: *moreni* Thomas 1897, *boxi* Thomas 1921, *sarae* Thomas and St. Leger 1926, and *somuncurensis*

Figure 4. External view of the dorsal coloration of different populations of *Lagidium*: A) southern Argentina (MACN 14313; Pilcaniyeu, Río Negro; here referred as *L. moreni*). B) north-western Argentina (MACN 34.258; Sierra de Velazco, La Rioja; here referred as *L. viscacia*). Not in scale.

Crespo 1963 (Figure 2B). Hayman (in Ellerman 1940), Pearson (1995) and Spotorno *et al.* (2004) used *boxi* as the appropriate name for southern Argentinean and Chilean samples. Within this context, the status of *moreni*, included by Hayman (in Ellerman 1940) under his concept of *viscacia* (against Osgood 1943:141, which suggested that this taxon would be closely allied to *boxi*) should be adequately addressed, since this name precedes *boxi*. The type locality of *moreni* is unclear, a fact that restrains taxonomic assessments. Thomas (1897: 466) first referred it to "hills near Chubut, Eastern Patagonia," but subsequently considered it as "unknown, as 'Chubut' is a province of considerable size, and there is no evidence as to the detailed location where the specimen was obtained" (Thomas 1921: 181). *Lagidium* is broadly distributed on western and central Chubut province, with some isolated population reaching its easternmost locality record near -65° W (Chebez *et al.* 2014). The specimens studied from Chubut and other areas of southern Argentina formed close clusters in the multivariate space, suggesting that only a single species is present in this area.

Table 2. Specimen scores of adult individuals of *Lagidium* (n = 55) for Principal Components 1 and 2, and for Canonical Variates 1 and 2 extracted from an eight-group discriminant function analysis. See materials and methods for the explanation of the abbreviations.

	CP1	CP2	CV1	CV2
SL	0.32	0.03	-0.28	0.85
LCI	0.32	0.07	0.30	-0.82
IB	0.19	0.03	0.18	-0.02
ZB	0.31	-0.04	-0.38	1.57
BB	0.21	-0.34	0.09	-1.06
LN	0.27	-0.01	0.17	-0.20
NW	0.24	-0.36	0.18	-0.68
FL	0.20	-0.11	-0.05	-0.02
DL	0.29	0.07	0.70	-0.6
IFW	0.02	0.60	2.26	-0.08
IFL	0.21	0.37	-0.68	0.91
TRL	0.28	0.09	-0.83	0.49
PalL	0.30	-0.05	-0.35	-0.48
BPP	0.26	-0.04	-1.09	-0.01
PWM3	0.28	0.01	0.35	-0.83
BuL	0.10	0.47	1.30	0.27
Eigenvalue	9.45	1.83	9.36	5.61
% Variance	0.59	0.11	49.5	29.69

Most of the samples from northwestern Argentina (*e. g.*, JU, LR, SA, SJ, TU) are characterized by yellowish-gray colorations, with diffuse to well-marked dorsal stripes, nasals not expanded anteriorly, and a broad dorsal root of the zygomatic process of the maxilla. At least five nominal forms were described from northwestern Argentina (*i. e.*, *tucumana* Thomas 1907, *vulcani* Thomas 1919, *lockwoodi* Thomas 1919, *famatinae* Thomas 1920, *tontalis* Thomas 1921; Figure 2B). Osgood (1943) argued that "The physical conditions under which the animals [in reference to these nominal forms] live in this region are fairly uniform and one finds it difficult to accept the assumption that all these names are well founded…it seems desirable to reduce all of these names to subspecific status." The cluster of specimens from western Bolivia in the multivariate space is close to those of northwestern Argentina and share a similar cranial architecture. However, both clusters differ in coloration, which was mostly grayish for those from western Bolivia. At least three nominal forms were described for Bolivia: *cuscus* Thomas 1907, *lutea* Thomas 1907, and *perlutea* Thomas 1907 (Figure 2B). Anderson (1997) recognized a single species in Bolivia (*L. viscacia*), with three subspecies (*L. v. cuscus*, *L. v. lutea*, *L. v. perlutea*), mapping several localities geographically close from the hypothesized distribution of *L. peruanum* in the Peruvian Highlands. In turn, Osgood (1943) referred populations from northern Chile and adjoining Boliv-

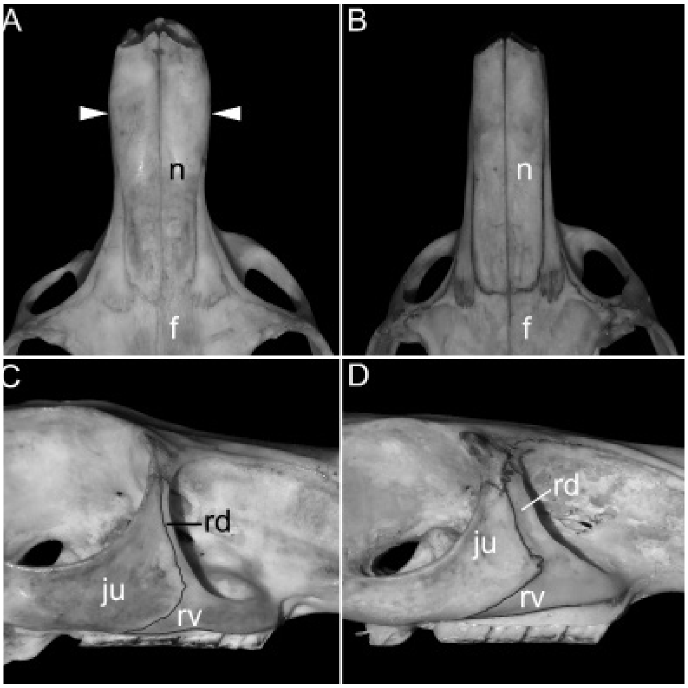

Figure 5. Anatomic details of the skulls of *Lagidium moreni* (A, C) *and L. viscacia* (B, D): A, C) MACN 13933 (NQ), note the nasals [n] anteriorly expanded and the narrow dorsal root of the zygomatic process of the maxilla [rd]; B, D) MACN 18829 (JU), presenting nasals [n] not expanded anteriorly and a broad dorsal root of the zygomatic process of the maxilla [rd]. Other abbreviations: f = frontal; ju = jugal; rv = ventral root of the zygomatic process of the maxilla.

Table 3. Classification matrix of geographic samples of *Lagidium* determined by the eight-group discriminant function analysis (see also Figure 3 and Table 2). See Materials and Methods for the explanation of the abbreviations.

Sample	BO	CH	JU	LR	NQ	PE	RN	SO	Error (%)
BO	3.00	0	0	0	0	0	0	0	0
CH	0	3.00	0	0	0	0	0	0	0
JU	0	0	10.00	0	0	1.00	0	0	9.09
LR	1.00	0	0	14.00	0	0	0	0	6.67
NQ	0	0	0	0	2.00	0	0	0	0
PE	0	0	0	0	0	6.00	0	0	0
RN	0	0	0	0	0	0	6.00	0	0
SO	0	1	0	0	0	0	0	3.00	25.00
Total	4.00	4.00	10.00	14.00	2.00	7.00	6.00	3.00	6.00

ian areas as *L. v. cuvieri*, suggesting their potential synonymy with *lutea*. With the evidences currently available, it is unclear whether those populations in northwestern Argentina and western Bolivia correspond to a single or several species, or whether they belong to *L. viscacia* s. s. (as some molecular evidences suggest; see the discussion below).

From the above, it is clear that the taxonomic scenario within *Lagidium* remains poorly defined, especially for populations towards the north-central portion of their distribution. This situation is shared by other genera of caviomorph rodents, in which discrete morphological differentiation in cranial features is apparently limited (*e. g., Dasyprocta* [*e. g.*, Teta and Lucero 2016], *Galea* [*e. g.*, Bezerra 2008]). Overall, our results contradicts the traditional view that considers *L. viscacia* as a largely distributed rodent species (*e. g.*, Spotorno and Patton 2015). The evidence reported here, plus the one derived from of previous molecular approaches (*e. g.*, Spotorno *et al.* 2004; Ledesma *et al.* 2009) strongly suggest that this taxon, as currently delimited, encompasses two or perhaps more species.

Our analysis, although preliminary, demonstrates that the Argentinean populations of *L. viscacia* correspond at least to two different species based on morphological and molecular evidences (cf. Ledesma *et al.* 2009). Those populations from west-central and southern Argentina (and possibly those on adjoining areas of southern Chile) could be preliminarily recognized as *L. moreni*, as discussed above. According to genetic data, this species is sister to *L. wolffsohni*, which is found farther to the south in montane areas of Argentina (Santa Cruz province) and Chile. Although we have not analyzed any specimens of *L. wolffsohni*, we preliminarily considered this species as distinct based on its striking orange coloration, short ears and large overall size (cf. Hayman [in Ellerman 1940]). As regards the samples from northwestern Argentina, the available evidence is inconclusive, since some molecular-based studies linked some populations in Jujuy (Argentina) and Antofagasta (Chile) to *L. viscacia* s. s. (specimens from central Chile; Spotorno *et al.* 2004), while data allocated these populations as a sister to a clade formed by the populations recognized here as *L. moreni* plus *L. wolffsohni* (Ledesma *et al.* 2009). Thus, without analyzing the topotypes of all nominal forms as well as adequate samples across the entire distributional range of the genus, it is premature to put forward any formal taxonomic proposal; we prefer to maintain those populations from northwestern Argentina, western Boliva and central Chile under *L. viscacia*.

Table 4. Variation on the occurrence of different types of dorsal coloration and development of the dorsal stripe among geographic samples of *Lagidium*. See materials and methods for the explanation of the abbreviations.

	Dorsal coloration		Dorsal stripe	
	grayish	**yellowish-gray**	**well marked**	**difuse**
BO	3 (100%)	0	1 (33.3%)	2 (6.7%)
CH	2 (100%)	0	2 (100%)	0
JU	2 (22.2%)	7 (77.8%)	8 (88.9%)	1 (11.1%)
LR	0	76 (100%)	3 (4.0%)	73 (96.0%)
ME	1 (100%)	0	1 (100%)	0
NQ	1 (16.7%)	5 (83.3%)	6 (100%)	0
RN[1]	18 (94.7%)	1 (5.3%)	18 (94.7%)	1 (5.3%)
SA	0	8 (100%)	4 (50.0%)	4 (50.0%)
SO	3 (100%)	0	3 (100%)	0
TU	0	1 (100%)	0	1 (100%)

[1] Two specimens from RN have a nearly uniform orange coloration, darker at the midline (MACN 36.135, 36.136; skulls unavailable); one specimen from SJ has a light gray dorsum frosted with white, and a light orange venter (MACN 18829).

Nominal forms such as *pallipes* Bennett 1835 and *viatorum* Thomas 1921 were not included in our study, nor were specimens from the northern Mendoza province, an area where the southern and northwestern groups could be in contact. Unfortunately, the only specimen examined from southern Mendoza province lacked its skull. Additional data, including molecular evidence, is much needed in order to clearly demarcate the distributional boundaries between species, especially in highly complex topographical areas such as the high Andean of northwestern Argentina, western Bolivia and northern Chile.

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Literature cited

Anderson, S. 1997. Mammals of Bolivia, taxonomy and distribution. Bulletin of the American Museum of Natural History 231:1-652.

Bezerra, A. 2008. Revisão taxonômica do gênero *Galea* Meyen, 1832 (Rodentia, Caviidae, Caviinae)." Ph.D. dissertation, Universidade de Brasília. Brasilia, Brazil.

Cabrera, A. 1961. Catálogo de los mamíferos de América del Sur. Parte II. Revista del Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" Ciencias Zoológicas 4, 309-732.

Chebez, J. C., U. F. J. Pardiñas, and P. Teta. 2014. Mamíferos terrestres de la Patagonia y el sur de Chile. Vazquez Mazzini Editores. Buenos Aires, Argentina.

Cherem, J. J., and J. Ferigolo. 2012. Descrição do sincrânio de *Cavia aperea* (Rodentia, Caviidae) e comparação com as demais espécies do gênero no Brasil. Papéis Avulsos de Zoologia 52:21-50.

Chiquito, E., G. D'Elia, and A. R. Percequillo. 2014. Taxonomic review of genus *Sooretamys* Weksler, Percequillo & Voss (Rodentia: Cricetidae: Sigmodontinae): an integrative approach. Zoological Journal of the Linnean Society, 171:842-877.

Crespo, J. A. 1963. Dispersión del chinchillón, *Lagidium viscacia* (Molina) en el noreste de Patagonia y descripción de una nueva subespecie (Mammalia; Rodentia). Neotrópica 9:61– 63.

Ellerman, J. R. 1940. The families and genera of living rodents. Vol. 1. Rodents other than Muridae. Trustes of the British Museum (Natural History).

Gallardo, M. H., and D. Reise. 1992. Systematics of *Aconaemys* (Rodentia, Octodontidae). Journal of Mammalogy 73:779-788.

Ledesma, K. J., F. A. Werner, A. E. Spotorno, and L. H. Albuja. 2009. A new species of Mountain Viscacha (Chinchillidae: *Lagidium* Meyen) from the Ecuadorean Andes. Zootaxa 2126:41-57.

Mann F., G. 1978. Los pequeños mamíferos de Chile. Zoología (Gayana) 40:1-342.

Musser, G. G. 1968. A systematic study of the Mexican and Guatemalan gray squirrel, *Sciurus aureogaster* F. Cuvier (Rodentia: Sciuridae). Miscellaneous Publications, Museum of Zoology, University of Michigan 137: 1-112.

Osgood, W. H. 1943. The mammals of Chile. Field Museum of Natural History, Zoological Series 30:1-268.

Pearson, O. P. 1948. Life history of mountain viscachas in Peru. Journal of Mammalogy 29:345-374.

Pearson, O. P. 1995. Annotated keys for identifying small mammals living in or near Nahuel Huapi National Park or Lanin National Park, southern Argentina. Mastozoología Neotropical 2:99-148.

Spotorno, A. E., and J. L. Patton. 2015. Superfamily Chinchilloidea Bennett, 1833. Pp. 762-783 in Mammals of South America, Vol. 2: Rodents (J. L. Patton, U. F. J. Pardiñas, and G. D'Elía, eds.). University of Chicago Press. Chicago, U. S. A.

Spotorno, A. E., J. P. Valladares, J. C. Marín, R. E. Palma, and C. Zuleta R. 2004. Molecular divergence and phylogenetic relationships of chinchillids (Rodentia: Chinchillidae). Journal of Mammalogy 85:384-388.

Teta, P., and S. O. Lucero. 2016. ¿Cuántas especies del género *Dasyprocta* (Rodentia, Dasyproctidae) hay en Argentina? Mastozoología Neotropical 23:193-199.

Thomas, O. 1897. On a new species of *Lagidium* from the eastern coast of Patagonia. Annals and Magazine of Natural History, series 6, 19:466-467.

Thomas, O. 1907. On a remarkable mountain viscacha from southern Patagonia, with diagnoses of other members of the group. Annals and Magazine of Natural History, series 7, 19:438– 444.

Thomas, O. 1921. A new mountain vizcacha (*Lagidium*) from N. W. Patagonia. Annals and Magazine of Natural History, series 9, 7:179-181.

Woods, C. A., and C. W. Kilpatrick. 2005. Infraorder Hystricognathi. Pp.1538-1600 in Mammal species of the world, 3rd ed., (Wilson, D. E., and D. M. Reeder, eds.). Johns Hopkins Press. Baltimore, U. S. A.

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Appendix 1.

List of specimens used in the morphological analyses, including skins and skulls. Acronyms correspond to the following collections. Argentina: Buenos Aires, Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" (MACN-Ma), Mendoza. Colección de Mamíferos del Instituto Argentino de Investigación de Zonas Áridas (CMI). Chile: Valdivia, Colección de Mamíferos de la Universidad Austral de Chile (UACH). US refers to field numbers of Daniel Udrizar Sauthier.

Lagidium moreni (*n* = 35). **Argentina**: *Chubut*: Cushamen (MACN-Ma 16521), Sierra de Talagapa (US, without number), Estancia La Maroma (US, without number). *Mendoza*: Malargue, 3 km S Puesto Peralito, 120 km E de Malargue (CMI without number). *Neuquén*: Catan-Lil, Las Coloradas (MACN-Ma 13620, 14312), Zapala, Parque Nacional Laguna Blanca (MACN-Ma 14897, 14898, 14899). *Río Negro*: Bariloche, El Bolsón (MACN-Ma 13936, 13937, 13946, 13947, 13949, 13951, 13952, 13955, 13956, 13958), Bariloche, Lago Martín (MACN-Ma 36.135, 36.136), Ñorquinco, Ñorquinco (MACN-Ma 13930, 13932, 13933, 13934, 13944, 16474), Pilcaniyeu, Pilcaniyeu (MACN-Ma 44.25, 14313), Valcheta, Campana Mahuida (MACN-Ma 14308, 14309, 14310, 14538, 14539, 14542).

Lagidium viscacia (*n* = 125): **Argentina**: *Jujuy*: locality not recorded (MACN-Ma 8.2, 31.11), Rinconada, Cerro Guadalupe (MACN-Ma 39.499, 39.500), Tilcara, Tilcara (MACN-Ma 8.18, 8.19), Valle Grande, Sierra de Zenta (MACN-Ma 32.66, 32.67), Yavi, La Laguna (MACN-Ma 27.99, 27.100), Departamento Yavi, Sierra de Cochinoca (MACN-Ma 14708), Yavi Chico (MACN-Ma 36.432, 41.54). *La Rioja*: locality not recorded (MACN-Ma 41.545), Famatina, Famatina (MACN-Ma 34.271), Sanagasta, Sierra de Velasco (MACN-Ma 34.202, 34.203, 34.204, 34.205, 34.206, 34.207, 34.208, 34.211, 34.212, 34.213, 34.214, 34.215, 34.217, 34.219, 34.221, 34.222, 34.223, 34.224, 34.225, 34.226, 34.227, 34.228, 34.229, 34.230, 34.231, 34.232, 34.233, 34.234, 34.236, 34.237, 34.238, 34.239, 34.240, 34.241, 34.242, 34.243, 34.244, 34.245, 34.246, 34.249, 34.250, 34.253, 34.254, 34.256, 34.251, 34.252, 34.257, 34.259, 34.260, 34.261, 34.263, 34.264, 34.265, 34.266, 34.271, 34.319, 34.1184, 34.1185, 34.1186, 34.1189, 34.1190, 34.1191, 34.1192, 34.1193, 34.1194, 34.1195, 34.1196, 34.1197, 34.1198, 34.1199, 34.1200, 34.1201, 34.1202, 34.1204, 34.1205, 34.1206, 34.1207, 34.1208, 34.1209, 34.1210, 34.1211, 34.1212, 34.1213). *Salta*: Los Andes, San Antonio de los Cobres (MACN-Ma 26.194, 26.195, 26.196, 26.197, 26.198, 26.199), Rosario de Lerma, Chorrillos (MACN-Ma 30.113, 30.114), Santa Victoria, Lizoite (MACN-Ma 41.26, 41.27, 41.37, 41.97). *San Juan*: Iglesia, Parque Nacional San Guillermo (MACN-Ma 18829). *Tucumán*: locality not recorded (MACN-Ma 4.382, 30.81), Chicligasta, Sierra del Aconquija (MACN 30.80). **Bolivia**: locality not recorded (MACN-Ma 13097). *La Paz*: Pedro Domingo Murillo, Nuestra Señora de La Paz (MACN-Ma 33.41, 33.42, 33.43), Pacajes (MACN-Ma 50.279, 50.280).

Lagidium peruanum (*n* = 6): **Chile**: *Tarapacá*: Parinacota (UACH 711, 712, 717, 719, 720, 721).

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Mammals of the Tamaulipeco Thorny Scrubland, Northwestern Coahuila, Mexico

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The 'Tamaulipeco' thorny scrubland is one of the most interesting habitats of northeastern Mexico. It is considered that almost 70 % of its original surface area has been lost. Although there are no formal studies about the side effects of this loss, it is likely that it threatens wildlife in this habitat, mammals included. In addition, few areas in the State of Coahuila have been properly documented. The aim of this study was to document the richness of wild mammals in the northeastern border of Coahuila within the priority terrestrial region known as "Tamaulipeco Scrubland of the Lower Rio Bravo". The richness of mammals was assessed through direct records by trapping methods for small, medium-sized and large mammals along with the use of camera traps. This was supplemented with indirect records through traces. The occurrence index and richness of the area index were calculated. In addition, dominance and evenness were both evaluated with the Simpson and the Shannon-Wiener indexes for small and medium-sized/large mammals separately. Thirty three mammal species (Table 2) were recorded in 34 days of recording effort. The richness recorded in the study area represents 31.8 % of the mammal wildlife reported for Coahuila. The high diversity in the area is evidenced by the Margalef index (5.13). The Simpson index for small mammals (0.241) indicates a higher dominance in relation to medium-sized/large mammals (0.215). The Shannon-Wiener index showed a lower evenness among small relative to medium-sized /large mammal species (1.821 vs. 1.858). The species richness recorded in the study area shows a high diversity supported by the Margalef index. Despite characteristics of some of the observed traces are inarguable for specie's identification index does not confirm its presence due to low indirect records, so the certain presence of these species need to be confirmed in future surveys. The large number of records for *Dicotyles angulatus* and *Odocoileus virginianus* is due to the location of the study area in a hunting zone were these are the main species hunted. It is likely that hunting activities by local inhabitants benefits the rest of the species recorded.

El matorral espinoso tamaulipeco es uno de los hábitats característicos del noreste de México. Se considera que cerca del 70 % de su superficie original se ha perdido. Aunque no existen estudios formales sobre sus efectos negativos, es probable que su pérdida ponga en peligro la fauna presente en este tipo de vegetación, incluidos los mamíferos. Sumado a esto, algunas regiones del estado de Coahuila no han sido bien documentadas. El objetivo del presente estudio fue conocer la riqueza de los mamíferos silvestres presentes en el límite noreste de Coahuila dentro de la región terrestre prioritaria "Matorral Tamaulipeco del Bajo Río Bravo". La riqueza de mamíferos se obtuvo mediante registros directos a través de la captura con trampas con cebo para mamíferos de tamaño pequeño, mediano y grande, además del uso de cámaras trampa. Se complementó con registros indirectos por medio de búsqueda de rastros. Se calculó el índice de ocurrencia y el índice de Margalef. Además, se evaluó la dominancia y la equidad mediante los índices de Simpson y Shannon-Wiener para los mamíferos pequeños y los medianos y grandes por separado. Con un esfuerzo de muestreo de 34 días se registraron 33 especies de mamíferos (Tabla 2). La riqueza en el área representa el 31.8 % de la mastofauna reportada para Coahuila. El índice de Margalef (5.13) mostró que la diversidad de la zona es alta. El índice de Simpson en los mamíferos pequeños (0.241) indica una mayor dominancia de las especies más abundantes con respectos a los mamíferos medianos y grandes (0.215). El índice de Shanon-Wiener mostró que la equidad entre especies fue menor en los mamíferos pequeños (1.821) que en los de tamaño mediano y grande (1.858). La riqueza registrada en el área de estudio demuestra la diversidad alta en la zona que es soportada por el índice de Margalef. A pesar de que las características de algunos de los rastros observados son indiscutibles para la identificación de la especie, el índice de ocurrencia no confirma su presencia debido al bajo número de registros indirectos de esas especies, por lo que la certera presencia de éstas debe corroborarse con futuros trabajos. El número alto de registros de *Dicotyles angulatus* y *Odocoileus virginianus* se debe a que el área de estudio está inmersa en una zona cinegética donde éstas son las principales especies utilizadas. Es probable que las actividades cinegéticas realizadas por los locatarios estén beneficiando al resto de las especies reportadas.

Key words: Camera trap; hunting; mammals; occurrence index; richness.

Introduction.

Northeastern Mexico comprises the States of Coahuila, Nuevo León, San Luis Potosí and Tamaulipas, and includes an interesting complex of habitats. One of these is the arid zone located in the boundary with the United States of America, which encompasses two vegetation types: the Chihuahuan desert of western Mexico and the Tamaulipeco thorny scrubland to the east (Rzedowski 2006). The latter has an approximate area of ~200.000 km^2 distributed in the States of Coahuila, Nuevo Leon and Tamaulipas, in Mexico, and southern Texas in the United States of America (Jiménez *et al.* 2012). Although this area is home to a high diversity of plant species, this vegetation type is currently considered as threatened by anthropogenic activities such as cattle raising (intensive/extensive), agriculture and different forest activities that have led to the loss in terms of habitat quality and

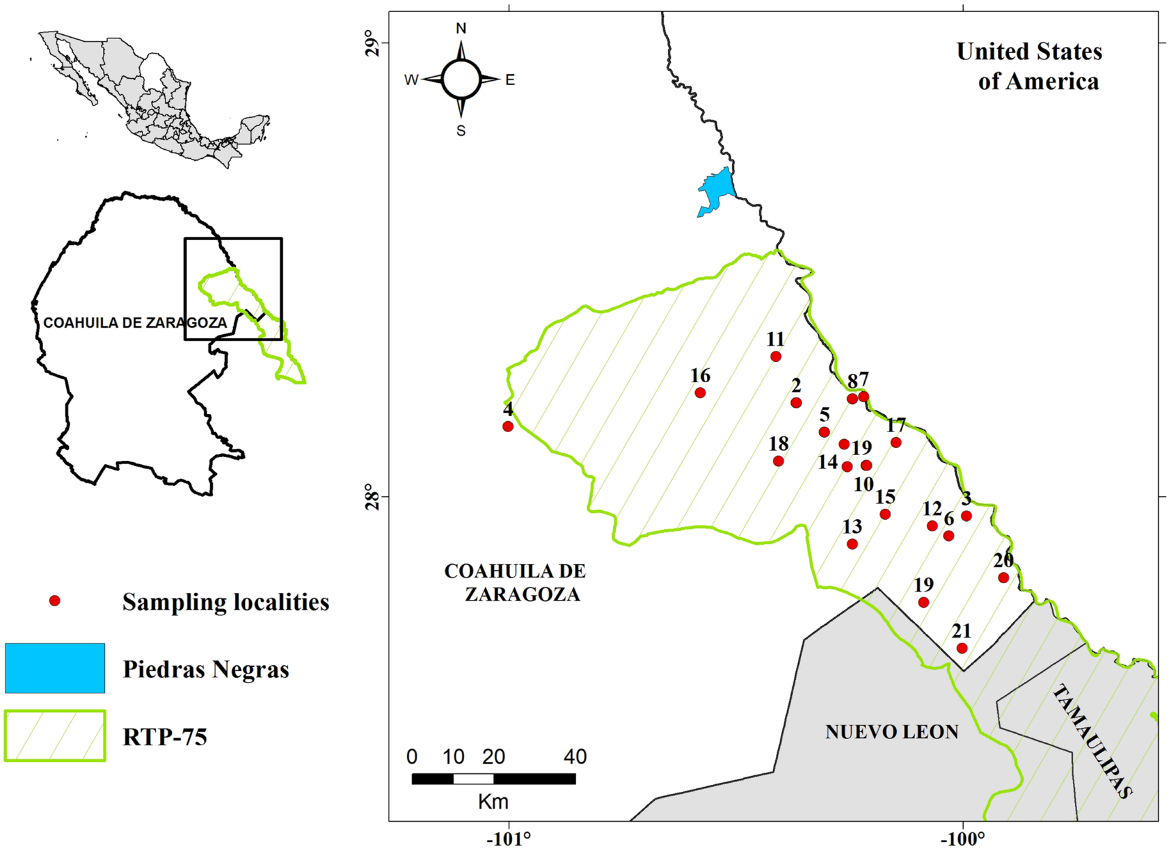

Figure 1. Location of the sampling area within the priority terrestrial region named Tamaulipeco Scrubland of the Lower Rio Bravo (RTP-75) located to the SSE of Piedras Negras in northeastern Coahuila. The name and location of collection sites are detailed in Annex 1.

number of plant species (Alanis *et al.* 2008; Jiménez *et al.* 2009; Mora-Donjuán *et al.* 2014). It is considered that over 90 % of its original surface area has been lost in Texas, while in 30 % is still preserved in northern Mexico (Arriaga *et al.* 2000). Although no formal studies on the negative effects are currently available, it is likely that the loss mentioned above would undoubtedly jeopardize the fauna present in this type of vegetation, including mammals.

The State of Coahuila de Zaragoza is the third largest political entity in Mexico and provides a variety of suitable habitats for a great diversity of mammals due to its geographical location and unique type of vegetation. This diversity has been studied on a large scale (Sánchez-Cordero *et al.* 2014), but not at local scales; as a result, some regions are not well documented. In general, studies on mammals in this State are scarce compared with those available for other entities (Guevara-Chumacero *et al.* 2001; Islas-Sánchez 2014). The knowledge of mammals in Coahuila is summarized in a general inventory (Baker 1956) and some other inventories elaborated for particular groups and regions and reported in the gray literature (Tavizon 1998; Juarez 2006; Mata 2012; Rodriguez 2013; Aguilar-Bucio 2014). Another piece of work focuses on the Cuatro Ciénegas Reserve (Contreras-Balderas *et al.* 2007). This area is one of the regions with the most intense hunting activity in the country, and includes an estimated 4.4 million hectares where hunting is practiced. Coahuila has a record of over one thousand ranches and *ejidos* with Wildlife Management and Exploitation Units (UMA in Spanish); Acuña, Zaragoza, Guerrero, Villa Union, Jimenez and Nava are the municipalities where the main hunting associations and guides are located (CONABIO 2012).

Due to these intense human activities in the area and the limited local knowledge of the mammalian fauna in the State, it is imperative to produce solid and reliable information concerning the wild populations of mammals that are found at local scales, since the lack of this basic information may result in the inadequate management of natural resources aiming at conservation and sustainable use in the area. For this purpose, this study recorded the richness of wild mammals present in an area comprising two municipalities in northeastern Coahuila, Mexico.

Materials and Methods.

Study area. The sampling area is located 70 km SSE of Piedras Negras in the municipalities of Guerrero and Hidalgo, in northeastern Coahuila, Mexico. It has an area of approximately 1,500 km^2 and the dominant vegetation type is the Tamaulipeco thorny scrubland plus small patches of xeric mesquite scrublands, oak forests and natural grassland. The area is located within one of the regions classified by the Mexican government as a priority terrestrial region called Tamaulipeco Scrubland of the Lower Rio Bravo (RTP-75) through the National Commission for the Knowledge and Use of Biodiversity (Figure 1). This scrubland vegetation is dominated by deciduous thorny species most of the year.

Figure 2. Some species recorded by sighting and camera traps in the study area. A) *Odocoileus virginianus*, B) *Sylvilagus audubonii*, C) *Eptesicus fuscus*, D) *Ictidomys mexicanus*, E) *Lepus californicus*, F) *Dicotyles angulatus*, G) *Mephitis mephitis*, H) *Conepatus leuconotus*, I) *Canis latrans*, and J) *Lynx rufus*.

Table 1. Figures used for each type of evidence to calculate the occurrence index. Modified from Boddicker et al. (2002). The "Type of Evidence" column has been added.

Type of Evidence	Quality of Evidence	Type of Record	Magnitude
Direct	Unambiguous	Collected species	10
		Observed species	10
Indirect	High quality	Bones	5
		Hair	5
		Identification by local residents	5
		Footprints	5
		Vocalizations and odoriferous substances	5
		Beds, burrows, trails, scratches and excavations	4
	Low quality	Feces	4
		Food remains	4

The species that predominate are the *gavia* or *huizache* (*Acacia* sp.), *paloverde* (*Cercidium* sp.), cenizo (*Leucophyllum* sp.), mesquite (*Prosopis* sp.), *amargoso* (*Castela tortuosa*) and *abrojos* (*Condalia* sp: INEGI 2009; Mora-Donjuán *et al.* 2014). The physiography of the study area is dominated by prairies and plains, the climate is dry and warm with a mean annual temperature above 22 °C, and with summer and winter rainfall greater than 18 % per year (Arriaga *et al.* 2000).

Methodology and Data Analysis. Three field trips were conducted in October 2013, March 2014 and June 2014, irregularly distributed in relation to the climatic season, giving a total of 34 days of sampling. Recordings were made using capture and trace methods. The traps used to capture non-flying small mammals (weight < 500 g), were 110 Sherman traps baited with a mixture of oat and vanilla extract placed at random along transects (such as ravines, fallen logs, close to potential burrows and in vegetated areas). The number of transects varied at each sampling site depending on the conditions of each. The age, sex and reproductive status of all specimens captured were recorded before releasing them. Some of these individuals were collected as reference specimens and were prepared conventionally as skin, skeleton, and tissue for deposit and cataloguing in the National Collection of Mammals (CNMA) of the Institute of Biology, *Universidad Nacional Autónoma de México.* All captured specimens were handled according to the guidelines of the American Society of Mammalogists (Sikes *et al.* 2011) using the scientific collector license FAUT-0070.

For flying mammals, it was not possible to conduct night captures with mist nets; hence, only daytime searches were carried out in potential shelters such as abandoned buildings, trees and caves. As regards medium-sized and large mammals (weight > 500 g), six Tomahawk traps of various dimensions baited with sardine were placed at distances of at least 400 m. In addition, 16 WVL WF118i_halfshutter camera traps with motion sensor were placed in water bodies or areas identified as animals trails by the continuous identification of tracks. The camera traps were set to operate 24 hours a day and with a minimum delay of 20 seconds between photographs. One day (24 hours) was regarded as one sampling event per camera trap station, considering as independent captures those individual photographs or groups of photographs by species recorded by each camera trap station in a single sampling event (Yasuda 2004). As a supplement, daytime surveys were conducted, each lasting between six to eight hours, across random free transects measuring one to five km long (Wilson and Delahay 2001), where sightings were recorded photographically using conventional cameras. Traces were also searched in these same surveys, including excreta, footprints, and remains such as hair and horns, all of which were identified through specialized guides (Aranda 2012; Elizalde-Arellano *et al.* 2014). From this evidence, the traces recorded were counted; if more than one was found in the same area, this was considered as a single record to avoid an overestimate of the data (Wilson and Delahay 2001). Bone remains and roadkill specimens of medium-sized and large species were collected, taking samples of tissue, and the skin and skeleton were prepared in the conventional manner for deposit in the biological collection. All specimens were identified using specialized guides (Hall 1981; Alvarez *et al.* 1994; Villa y Cervantes 2003; Medellín *et al.* 2008) and by comparisons with CNMA voucher specimens.

To confirm the presence of the species, we used the occurrence index proposed by Boddicker *et al.* (2002). This index assigns values to the various types of evidence: ambiguous, high-quality and low-quality, and assesses the presence of species from the accumulation of these types of evidence (Table 1). When the cumulative points reach a value of 10, it is concluded that the species is present on the site. The nomenclature used for the species was as proposed by Ramírez-Pulido *et al.* (2014).

The species richness of mammals in the study area was calculated using direct data through the Margalef index with the formula $DMg = S - 1/1n\ N$, where S is the number of species and N is the total number of individuals (Moreno 2001). In addition, dominance and evenness were estimated through the Shannon-Wiener and Simpson indices (Moreno 2001) for small, medium-sized and large mammals separately (Monroy-Vilchis *et al.* 2011).

Results

A sampling effort of 34 days resulted in the recording of 33 mammal species in the study area, belonging to 7 orders, 16 families and 30 genera (Table 2). The orders best represented were Carnivora and Rodentia, with 39.4 % and 30.3 % of the total number of species, respectively; the families with the largest number of species were Felidae, Heteromyidae and Cricetidae, with 12.1 % each. A total of 709 records were obtained, 510 of which were direct and 199 indirect.

The small mammals captured (196 individuals) correspond to the orders Rodentia and Chiroptera, belonging to five families and 12 species. Ten species of rodents were recorded, the species with the highest number of records

Table 2. Mammals recorded in the municipalities of Guerrero and Hidalgo in northeastern Coahuila; the type of record for each one is shown. Direct records: C = capture, T = camera trapping, and S = sighting; indirect records: E = excreta, F = footprints, H = hair, A = antlers. Direct records (DR), number of individuals per capture, photograph or sighting (IPS). Indirect records (IR) and number of indirect records (NIR).

Order	Family	Species	TRD	IPS	IR	NIR
Didelphimorphia	Didelphidae	*Didelphis virginiana*	C	1	E, F	1
Cingulata	Dasypodidae	*Dasypus novemcinctus*	–	0	F	1
Lagomorpha	Leporidae	*Lepus californicus*	C, S	26	–	–
		Sylvilagus audubonii	C, T, S	19	–	–
		Sylvilagus floridanus	C, T, S	35	–	–
Rodentia	Sciuridae	*Sciurus* sp.	C	1	–	–
		Ictidomys mexicanus	C, S	17	E, F	8
	Cricetidae	Sigmodon hispidus	C	7	–	–
		Neotoma micropus	C	4	–	–
		Onychomys leucogaster	C	12	–	–
		Peromyscus leucopus	C	85	–	–
	Heteromyidae	*Perognathus merriami*	C	21	–	–
		Chaetodipus hispidus	C	11	–	–
		Dipodomys merriami	C	31	–	–
		Dipodomys ordii	C	2	–	–
Carnivora	Felidae	*Lynx rufus*	T, S	3	E, F	10
		Puma concolor	–	0	E, F	5
		Herpailurus yagouaroundi	S	2	F	1
		Leopardus weidii	–	0	E, F	2
	Canidae	*Canis latrans*	T, S	21	E, F	48
		Urocyon cinereoargenteus	C, S	7	E, F	6
	Mustelidae	*Taxidea taxus*	S	1	–	–
	Mephitidae	*Conepatus leuconotus*	C	1	F	1
		Mephitis mephitis	C	1	–	–
	Procyonidae	*Bassariscus astutus*	S	1	E	1
		Nasua narica	–	0	E, F	2
		Procyon lotor	C, T	5	E, F, H	25
	Ursidae	*Ursus americanus*	–	0	E, H	11
Chiroptera	Molossidae	*Tadarida brasiliensis*	C	3	–	–
	Verpertilionidae	*Eptesicus fuscus*	C	2	–	–
Artiodactyla	Tayassuidae	*Dicotyles angulatus*	C, T, S	110	E, F, H	15
	Cervidae	*Odocoileus virginianus*	C, T, S	81	E, F, A	61
		Odocoileus hemionus	–	0	A	1
Total records				510		199

being *Peromyscus leucopus*, *Dipodomys merriami* and *Perognathus merriami* (85, 31 and 21 individuals, respectively). One specimen of the genus *Sciurus* could not be identified to species because it was a poorly preserved roadkill specimen. On the other hand, the bat species found in shelters were *Eptesicus fuscus* within cavities at the base of a dead tree, and *Tadarida brasiliensis* inside an abandoned building.

The medium-sized and large mammals (505 records in total) belong to five orders, 11 families and 21 species. The species with the highest number of direct records were *Dicotyles angulatus* (110), *Odocoileus virginianus* (81) and *Sylvilagus floridanus* (35, Figure 2). The occurrence index by Boddicker *et al.* (2002) confirmed the presence of all species except *Dasypus novemcinctus*, *Puma concolor, Conepatus leuconotus, Nasua narica* and *Ursus americanus*, which were identified by indirect methods only.

A total of 39 specimens were deposited in the National Collection of Mammals (CNMA; Annex 1). Of the total species recorded, four are under some protection category by the Mexican government according to NOM-059-2010 (SEMARNAT 2010): *Herpailurus yagouaroundi* and *Taxidea taxus* as "threatened", and *Ursus americanus* and *Leopardus weidii* in the "special protection" category. On the other hand, the species *Lynx rufus*, *Puma concolor, Herpailurus yagouaroundi*, and *Ursus americanus* are listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora

(CITES), while *Leopardus weidii* is listed in Appendix I (2016). The only endemic species recorded was *Ictidomys mexicanus*.

The Margalef index (5.13) revealed that the total diversity in the area is high. The Simpson index for small mammals (0.241) points to a greater dominance of the most abundant species relative to medium-sized and large mammals (0.215). On the other hand, the Shannon-Wiener index showed that the evenness between species was lower for small mammals (1.821) relative to medium-sized and large mammals (1.858).

Discussion

Despite the fact that Mexico still preserves 30 % of the surface area originally covered with Tamaulipeco thorny scrubland, it is considered that there is an insufficient knowledge about the fauna that inhabits it (Arriaga *et al.* 2000). In addition, the low number of studies that are carried out in Coahuila due to safety issues and the low number of protected natural areas in the state highlight the importance of this work.

Coahuila is home to 107 species of mammals: 80 terrestrial and 27 flying ones (Sánchez-Cordero *et al.* 2014). In all, 31.8 % of the mammal fauna of the State was recorded in the study area, demonstrating the high diversity in the area supported by the Margalef index (5.13). The three rodent species with the highest number of records are widely distributed species. *P. leucopus* is highly tolerant to various environmental conditions such as those that characterize the study area, while *D. merriami* is considered to be locally abundant in other studies (Castillo 2005; Chávez and Espinosa 2005; Frisch-Jordan and Arita 2005).

Ictidomys mexicanus was the only endemic species recorded (Ramírez-Pulido *et al.* 2014), with only three individuals captured. The number of sightings (13) was higher, supported by indirect records including excreta and burrows; this suggests a high abundance of the species in the area. This is consistent with other studies that indicate that this species is relatively abundant across its areas of distribution (Ceballos and Galindo 1984; Valdez and Ceballos 1991).

The daytime searches of bat shelters detected an abandoned building used as a warehouse that was inhabited by a large colony of at least 15 individuals of *Tadarida brasiliensis*. Due to the difficulty of capturing all individuals and that this a "segregationist" species, *i. e.*, it shares its shelters with just a few species (Arita 1993), it is considered that the whole colony belonged to this species only. The second Chiroptera species recorded was *Eptesicus fuscus* with about four individuals observed and captured inside cavities at the base of a dead tree, with no other structure close to it. This type of shelter is characteristic of the species (Tellez-Giron 2005).

The occurrence index by Boddicker *et al.* (2002) did not confirm the presence of five species (*Dasypus novemcinctus, Nasua narica, Conepatus leuconotus, Puma concolor* and *Ursus americanus*), since these were detected through a low number of indirect records. However, the traces observed possess particular characteristics that facilitate their identification. *D. novemcinctus* leaves a characteristic and unmistakable trail of footprints; the unique features of these fingerprints derive from fingers being short with long thick claws with rounded tips; in addition, in some cases the drag of the tail leaves a trace in soil (Aranda 2012). In *P. concolor,* the tracks could only be misidentified with those of the jaguar (*Panthera onca*) because of the similar size of the fingerprints. However, it was considered that the habitat is more favorable for the cougar, in addition to the fact that several specimens of this species have been observed by local inhabitants and workers. The footprints of *C. leuconotus* are similar to those of *C. semistriatus*, but these two species have supplementary distributions and the study area coincides with the distribution of *C. leuconotus* (Aranda 2012). This was confirmed by a roadkill individual found in a survey trip to the site (Figure 2H). In the case of *N. narica* and *U. americanus*, evidence records are scarce. In the case of *N. narica*, these comprise only two traces; in the case of *U. americanus*, in presumed excreta. The margay (*Leopardus weidii*) was recorded based on two prints that match the characteristics and size of the species, although these can be confused with domestic cat traces (Aranda 2012), no margay specimens were observed in the area.

The large number of records of *Dicotyles angulatus* (n = 110) and *Odocoileus virginianus* (n = 81) is due to the fact that the study area is located within a hunting zone where these are the main species used. A skull and vertebrae of one specimen were collected which were subsequently identified as a mule deer (*Odocoileus hemionus*). The identification is based on the comparison with specimens in the National Collection of Mammals, where the size of the lacrimal bone allowed the identification as *O. hemionus*. The mule deer lives in isolated geographical patches, and hunting is permitted under the "special license" modality (Galindo-Leal 1993). However, the hunting ranches in the area do not report the mule deer among the game species used.

Hunting is an activity with strong cultural roots that led to the disappearance or marked decline of the local populations of some species; as a result, the mule deer has been subject to strict regulation, including the creation of hunting zones (SAHR 1993). This type of scheme has been widely popularized in the northern States of Mexico and covers an area of more than 18 million hectares, making it one of the most important sources of income in the region. Recently, hunting has been linked to a number of benefits for conservation because it allows the controlled use of the resource in extensive areas and represents a significant income that allows managing the area to preserve its environmental quality in terms of vegetation that is favorable for the presence of game animals (2010 Rengifo-Gallego). The maintenance or establishment of a suitable habitat for game species (natural vegetation within the agricultural matrix, mosaic landscape or boundaries), as well as the supply of food and water, seem to favor other species as well (Arroyo *et al.* 2013). In our study area, the management and conservation of the habitat benefits not only the game species but also the rest of species present in the area. This is reflected in the high number of species recorded and in the presence of large carnivores such as the black bear (*U. americanus*) and the cougar (*P. concolor*).

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Literature cited

Aguilar-Bucio, L. M. 2014. Monitoreo de la diversidad, abundancia y riqueza de especies de fauna silvestre en el proyecto minero "Carlos II", Palaú, Coahuila, México. Tesis de licenciatura. Universidad Autónoma Agraria Antonio Narro. Saltillo, México.

Alanís, E., J. Jiménez, O. A. Aguirre, J. E. Treviño, E. Jurado, and M. A. González. 2008. Efecto del uso del suelo en la fitodiversidad del matorral espinoso tamaulipeco. Ciencia Universidad Nacional Autónoma de Nuevo León 1:56-62.

Álvarez, T., T. Álvarez-Castañeda, and J. C. López-Vidal. 1994. Claves para murciélagos mexicanos. Centro de Investigaciones del Noroeste, S. C. and Escuela Nacional de Ciencias Biológicas del Instituto Politécnico Nacional. La Paz, México.

Aranda, J. M. S. 2012. Manual para el rastreo de mamíferos silvestres de México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. Ciudad de México, México.

Arita, H. T. 1993. Conservation biology of the cave bats of Mexico. Journal of Mammalogy 74:693-702.

Arriaga, L., J. M. Espinoza, C. Aguilar, E. Martínez, L. Gómez, and E. Loa (coord.). 2000. Regiones terrestres prioritarias de México. Comisión Nacional para el Conocimiento y uso de la Biodiversidad. Ciudad de México, México.

Arroyo, B., M. Delibes-Mateos, J. Caro, A. Estrada, F. Mougeot, S. Díaz-Fernández, F. Casas, and J. Viñuela. 2013. Efecto de la gestión para las especies de caza menor sobre la fauna no cinegética. Ecosistemas 22:27-32.

Baker, R. H. 1956. Mammals of Coahuila, Mexico. University Kansas Publications, Museum Natural History 9:125-335.

Boddicker, M., J. J. Rodriguez, and J. Amanzo. 2002. Indices for assessment and monitoring of large mammals within an adaptive management framework. Environmental Monitoring and Assessment 76:105-23.

Castillo, R. A. 2005. *Dipodomys merriami*. Pp. 616- 617 in Los Mamíferos Silvestres de México (Ceballos, G., and G. Oliva, Coord.). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Fondo de Cultura Económica. Ciudad de México, México.

Ceballos, G., and C. Galindo. 1984. Mamíferos Silvestres de la Cuenca de México. Editorial Limusa. Ciudad de México, México.

Cites. 2016. Convención Internacional sobre el Comercio de Especies Amenazadas de Fauna y Flora. Apéndices I, II and II. Disponible en https://cites.org/esp/app/appendices.php Última consulta 16 junio 2016.

Chávez, C. B., and L. A. Espinosa. 2005. Peromyscus leucopus. Pp. 744-745 en Los Mamíferos Silvestres de México (Ceballos, G. and G. Oliva, Coord.). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Fondo de Cultura Económica. Ciudad de México, México.

CONABIO. 2012. Proyecto de Evaluación de las Unidades de Manejo para la Conservación de la Vida Silvestre (UMA) (1997-2008). Resultados de la Fase I: Gestión y Administración. Proyectos CONABIO: HV003, HV004, HV007, HV012 y HV019. Disponible en http://www.biodiversidad.gob.mx/usos/UMAs_pdf/Informe_CONABIO_Proyecto_UMA_FASE_I.pdf

Contreras-Balderas, A. J., D. J. Hafner, J. H. Lopez-Soto, J. M. Torres-Ayala, and S. Contreras-Arquieta. 2007. Mammals of the Cuatro Ciénegas basin, Coahuila, México. The Southwestern Naturalist 52:400-409.

Elizalde-Arellano, C., J. C. López-Vidal, L. Hernández, J. W. Laundré, and F. M. Morales-Mejía. 2014. Bases para el monitoreo de dos especies de carnívoros medianos en la Reserva de la Biosfera de Mapimí, Durango. Instituto Politécnico Nacional, Escuela Nacional de Ciencias Biológicas. Guía de mamíferos de la Reserva de la Biosfera de Mapimí SNIB-CONABIO, proyecto GT022. Ciudad de México, México. Disponible en http://www.conabio.gob.mx/institucion/proyectos/resultados/GT022_Anexo_Guia_Mamiferos.pdf

Frisch-Jordán, A., and H. T. Arita. 2005. Perognathus merriami. Pp. 655-656 en Los Mamíferos Silvestres de México (Ceballos, G., and G. Oliva, Coord.). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Fondo de Cultura Económica. Ciudad de México, México.

Galindo Leal, C. 1993. Densidades poblacionales de los venados cola blanca, cola negra y bura en Norteamérica. Pp. 371-391 en Avances en el estudio de los Mamíferos de México. (Medellín, R. A., and G. Ceballos, eds). Publicaciones especiales, Vol. 1, Asociación Mexicana de Mastozoología, A. C. Ciudad de México, México.

Guevara-Chumacero, L. M., R. López-Wilchis, and V. Sánchez-Cordero. 2001. 105 años de investigación mastozoológica en México (1890-1995): una revisión de sus enfoques y tendencias. Acta Zoológica Mexicana (n. s.) 83:35-72.

Hall, E. R. 1981. The mammals of North America. John Wiley, Hobaken, New Jersey, U. S. A.

Instituto Nacional De Estadística y Geografía (INEGI). 2009. Guía para la interpretación de cartografía uso del suelo y vegetación Escala 1:250 000 Serie III. Instituto Nacional de Estadística y Geografía. Ciudad de México, México.

Islas-Sánchez, L. 2014. Estado del conocimiento actual de los mamíferos terrestres en México. Tesis Facultad de ciencias biológicas y agropecuarias. Universidad Veracruzana. Tuxpan, México.

Jiménez, J., E. Alanís, O. Aguirre, M. Pando, and M. A. González. 2009. Análisis sobre el efecto del uso del suelo en la diversidad estructural del matorral espinoso tamaulipeco. Madera y Bosques 3:5-20.

Jiménez, J., E. Alanís-Rodríguez, J. L. Ruiz-González, M. A. González-Tagle, J. I. Yerena-Yamalle, and G. J. Alanís-Flores. 2012. Diversidad de la regeneración leñosa del matorral espinoso tamaulipeco con historial agrícola en el noreste de México. Ciencia Universidad Nacional Autónoma de Nuevo León 58:66-71.

Juárez, D. J. 2006. Diversidad de pequeños mamíferos asociados a poblaciones de Pinus pinceana Gordon en Coahuila y Zacatecas. Tesis de licenciatura. Universidad Autónoma Agraria Antonio Narro. Saltillo, México.

Mata, G. C. 2012. Abundancia relativa de mamíferos terrestres Grandes y Medianos en el Área Reforestada de la Sierra de Zapalinamé, Coahuila México. Tesis de licenciatura Universidad Autónoma Agraria Antonio Narro. Saltillo, México.

Medellín, R. A., H. T. Arita, and O. Sánchez. 2008. Identificación de los Murciélagos de México, claves de campo. Segunda Edición. Asociación Mexicana de Mastozoología, Publicaciones especiales. Ciudad de México, México.

Monroy-Vilchis, O., M. M. Zarco-González, J. Ramírez-Pulido, and U. Aguilera-Reyes. 2011. Diversidad de mamíferos de la Reserva Natural Sierra Nanchititla, México. Revista Mexicana de Biodiversidad 82:237-248.

Mora-Donjuán, C. A., E. A. Rubio-Camacho, E. Alanís-Rodríguez, J. Jiménez-Pérez, M. A. González-Tagle, J. M. Mata-Balderas, and A. Mora-Olivo. 2014. Composición y diversidad vegetal de un área de Matorral Desértico Micrófilo con historial pecuario en el noreste de México. Polibotánica 38:53-66.

Moreno, C. 2001. Métodos para medir la biodiversidad. M&T-Manuales y Tesis SEA. Zaragoza, España.

Ramírez-Pulido, J., N. González-Ruiz, A. L. Gardner, and J. Arroyo-Cabrales. 2014. List of recent land mammals of México, 2014. Special Publications, Museum of Texas Tech University 63:1-69.

Rengifo-Gallego, J. I. 2010. Caza y turismo cinegético como instrumentos para la conservación de la naturaleza. Anales de Geografía 30:163-186.

Rodríguez-Rodríguez, S. A. 2013. Estimación de abundancia relativa de mamíferos terrestres grandes y medianos mediante fototrampeo en el área de reforestación Zapalinamé, Saltillo, Coahuila. Tesis de licenciatura. Universidad Autónoma Agraria Antonio Narro. Saltillo, México.

Rzedowski, J. 2006. Vegetación de México. 1ra. ed. digital. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. Ciudad de México, México.

Sánchez-Cordero, V., F. Botello, J. J. Flores-Martínez, R. A. Gómez-Rodríguez, L. Guevara, G. Gutiérrez-Granados, G., and A. Rodríguez-Moreno. 2014. Biodiversidad de Chordata (Mammalia) en México. Revista Mexicana de Biodiversidad, Supl. 85:S496-S504.

SARH. 1993. Plan Maestro para la instalación y operación de ejidos cinegéticos: Viabilidad Socioeconómica y diagnóstico técnico. Instituto Nacional de Ecología. Subsecretaria Forestal y de Fauna Silvestre. Disponible en http://repositorio.inecc.gob.mx/ae2/ae_354.333_m495-8_t.2.pdf

SEMARNAT. 2010. Norma Oficial Mexicana NOM-059-ECOL-2010. Protección ambiental. Especies nativas de México de flora y fauna silvestres. Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio. Lista de especies en riesgo. Diario Oficial de la Federación. Ciudad de México, México.

Sikes, R. S., W. L. Gannon, and The Animal Care and Use Of The American Society Of Mammalogists. 2011. Guidelines of the American Society of Mammalogists for the use of wild animals in research. Journal of Mammalogy 92:235-253.

Tavizon, G. J. 1998. Estudio del nicho alimenticio de los mamíferos depredadores del orden Carnívora en la Sierra del Carmen, Noroeste de Coahuila, México. Tesis de posgrado. Universidad Autónoma de Nuevo León. Facultad de Ciencias Biológicas. Monterrey, México.

Tellez-Girón, G. 2005. *Eptesicus fuscus*. Pp. 263- 264 in Los Mamíferos Silvestres de México (Ceballos, G., and G. Oliva, Coord.). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Fondo de Cultura Económica. Ciudad de México, México.

Valdéz, M., and G. Ceballos. 1991. Historia natural, alimentación y reproducción de la ardilla terrestre (*Spermophilus mexicanus*) en una pradera intermontana. Acta Zoológica Mexicana (n. s.) 43:1-31.

Villa, R. B., and F. A. Cervantes. 2003. Los mamíferos de México. Grupo Editorial Iberoamericana, Instituto de Biología, Universidad Nacional Autónoma de México. Ciudad de México, México.

Wilson, G. J., and R. J. Delahay. 2001. A review of methods to estimate the abundance of terrestrial carnivores using field signs and observation. Wildlife Research 28:151-164.

Yasuda, M. 2004. Monitoring diversity and abundance of mammals with camera traps: a case study on Mount Tsukuba, central Japan. Mammal Study 29:37-46.

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Appendix 1. Species registered per locality, for the collected specimens the catalog number of the reference at the National Mammal Collection (CNMA), Institute of Biology, UNAM, is given. The rest of the records are indirect, as well as sighting and phototrap.

Locality 1. 5.25 km NW La Burra (Trinidad), Mpio. Guerrero, 200 m (28° 4' 9.5", -100° 12' 46.1"). Species: *Sigmodon hispidus* (CNMA 47022), *Canis latrans, Chaetodipus hispidus* (CNMA 47014), *Conepatus leuconotus, Dasypus novemcinctus, Dicotyles angulatus, Dipodomys merriami, Dipodomys ordii* (CNMA 47012, 47013), *Ictidomys mexicanus, Lepus californicus, Lynx rufus, Mephitis mephitis, Odocoileus virginianus, Onychomys leucogaster, Perognathus merriami, Peromyscus leucopus* (CNMA 47020, 47021), *Procyon lotor, Puma concolor, Sigmodon hispidus, Sylvilagus audubonii, Sylvilagus floridanus, Urocyon cinereoargenteus, Ursus americanus.*

Locality 2. 9.5 km NW El Gato, Mpio. Guerrero, 224 m (28° 12' 26.4", -100° 22' 3.4"). Species: *Onychomys leucogaster* (CNMA 47016), *Canis latrans, Dicotyles angulatus* (CNMA 46994, 46995), *Dipodomys merriami* (CNMA 47011), *Ictidomys mexicanus, Lepus californicus, Odocoileus virginianus* (CNMA 47002-47007), *Perognathus merriami* (CNMA 47015), *Peromyscus leucopus* (CNMA 47017 to 47019), *Sylvilagus audubonii, Sylvilagus floridanus, Urocyon cinereoargenteus.*

Locality 3. 4.25 km SW Santa Eulalia, Mpio. Hidalgo, 217 m (27° 57' 28.53", -99° 59' 31.08"). Species: *Canis latrans* (CNMA 46984).

Locality 4. 5.75 km NNW La Estancia, Mpio. Guerrero, 186 m (28° 9' 19.3", -101° 0' 9.8"). Species: *Procyon lotor* (CNMA 46985).

Locality 5. 1.5 km NE El Gato, Mpio. Guerrero, 235 m (28° 8' 35.2", -100° 18' 18.7"). Species: *Procyon lotor* (CNMA 46986), *Canis latrans, Dicotyles angulatus, Neotoma micropus, Odocoileus virginianus* (CNMA 47008), *Ursus americanus.*

Locality 6. 5 km SSE San Francisco, Mpio. Hidalgo, 205 m (27° 54' 50.9", -100° 1' 51.2"). Species: *Tadarida brasiliensis* (CNMA 47009, 47010), *Canis latrans, Lepus californicus, Odocoileus virginianus, Sylvilagus audubonii.*

Locality 7. 12.25 km NNW La Estancia, Mpio. Guerrero, 190 m (28° 13' 14.3", -100° 13' 7.3"). Species: *Dicotyles angulatus* (CNMA 46987), *Lynx rufus, Sylvilagus audobonii, Tadarida brasiliensis.*

Locality 8. 11.75 km NNW La Estancia, Mpio. Guerrero, 190 m (28° 12' 58.5", -100°14'37.5"). Species: *Dicotyles angulatus* (CNMA 46988 to 46990, 46993), *Canis latrans, Herpailurus yagouaroundi, Ictidomys mexicanus, Lepus californicus, Lynx rufus, Nasua narica, Odocoileus hemionus, Odocoileus virginianus* (CNMA 47000), *Peromyscus leucopus, Procyon lotor, Sylvilagus audubonii, Sylvilagus floridanus, Urocyon cinereoargenteus.*

Locality 9. 5.25 km SSW La Estancia, Mpio. Guerrero, 208 m (28° 4' 9.8", -100° 12' 44.9"). Species: *Dicotyles angulatus* (CNMA 46991), *Lepus californicus, Odocoileus virginianus.*

Locality 10. 6.25 km SW La Estancia, Mpio. Guerrero, 212 m (28° 4' 1.4", -100° 15' 16.8"). Species: *Dicotyles angulatus* (CNMA 46992), *Canis latrans, Dipodomys ordii, Lepus californicus, Lynx rufus, Neotoma micropus, Odocoileus virginianus, Procyon lotor, Puma concolor, Sylvilagus audubonii, Sylvilagus floridanus.*

Locality 11. 3.5 km W Guerrero, Mpio. Guerrero, 239 m (28° 18' 35.1", -100° 24' 43.0"). Species: *Dicotyles angulatus* (CNMA 46996), *Bassariscus astutus, Canis latrans, Didelphis virginiana, Dipodomys merriami, Herpailurus yagouaroundi, Ictidomys mexicanus, Leopardus weidii, Lepus californicus, Odocoileus virginianus, Perognathus merriami, Peromyscus leucopus, Procyon lotor, Sylvilagus floridanus, Urocyon cinereoargenteus, Ursus americanus.*

Locality 12. 7.25 Km ESE San Enrique, Mpio. Hidalgo (27° 56' 10.7", -100° 4' 2.7"). Species: *Odocoileus virginianus* (CNMA 46998), *Canis latrans, Dicotyles angulatus, Ictidomys mexicanus, Lepus californicus, Lynx rufus, Procyon lotor, Sylvilagus audubonii, Taxidea taxus.*

Locality 13. 11.25 Km SE San Enrique, Mpio. Hidalgo, 202 m. (27° 53' 45.4", -100° 14' 35.9"). Species: *Odocoileus virginianus* (CNMA 46999), *Peromyscus leucopus.*

Locality 14. 5.5 km W La Estancia, Mpio. Guerrero, 219 m (28° 6' 60", -100° 15' 42.2"). Species: *Odocoileus virginianus* (CNMA 47001), *Bassariscus astutus, Canis latrans, Dicotyles angulatus, Ictidomys mexicanus, Procyon lotor, Sylvilagus audobonii, Sylvilagus floridanus.*

Locality 15. 5 Km NW San Enrique, Mpio. Hidalgo, 216 m (27° 57' 43.7", -100° 10' 17.9"). Species: *Odocoileus hemionus* (CNMA 46997), *Canis latrans, Chaetodipus hispidus, Dicotyles angulatus, Dipodomys merriami, Herpailurus yagouaroundi, Lepus californicus, Lynx rufus, Neotoma micropus, Odocoileus virginianus, Onychomys leucogaster, Perognathus merriami, Peromyscus leucopus, Procyon lotor, Puma concolor, Sylvilagus audubonii, Sylvilagus floridanus, Urocyon cinereoargenteus, Ursus americanus.*

Locality 16. 4.7 Km NE Santa Mónica, Mpio. Guerrero, 308 m. (28° 13' 44.6", -100° 34' 44.5"). Species: *Dicotyles angulatus, Procyon lotor.*

Locality 17. 6.17 Km ENE La Estancia, Mpio. Guerrero, 181 m (28° 7' 13.6", -100° 8' 50.2"). Species: *Canis latrans, Dicotyles angulatus, Didelphis virginiana, Eptesicus fuscus, Ictidomys mexicanus, Lepus californicus, Lynx rufus, Neotoma micropus, Odocoileus virginianus, Perognathus merriami, Peromyscus leucopus, Procyon lotor, Sylvilagus audubonii, Sylvilagus floridanus, Urocyon cinereoargenteus, Ursus americanus.*

Locality 18. 2.7 Km ESE Agua Fría, Mpio. Guerrero, 266 m (28° 04' 45.5", -100° 24' 22.0"). Species: *Sylvilagus audubonii.*

Locality 19. 2 Km N Rancho Palo Blanco, Mpio. Hidalgo, 203 m (27° 46' 04.7', -100° 05' 11''). Species: *Ursus americanus.*

Locality 20. 4.97 Km NW Villa Hidalgo, Mpio. Hidalgo, 153 m (27° 49' 19.4', -99° 54' 36.1''). Species: *Lepus californicus.*

Locality 21. 6 Km SW Rancherías, Mpio. Hidalgo, 218 m. (27° 40' 1.2', -100° 0' 08''). Species: *Odocoileus virginianus.*

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Hunters´ Landscape accessibility and daily activity of ungulates in the Yasuní Biosphere Reserve, Ecuador

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Ungulates are one of the most important groups in terrestrial ecosystems across the tropics. Also, ungulates are an important source of protein for people who inhabit tropical forests, and numerous studies have been conducted to evaluate the impact of hunting on the size of ungulate populations. However, little is known about other potential effects of hunting on these species. This study aims to analyze the effect of landscape accessibility to hunters on the daily activities of ungulates in Yasuní Biosphere Reserve, a protected area located in the Amazon region of Ecuador. We compared activity patterns (*i. e.,* distribution of hours of activity along the day) and activity levels (*i. e.,* proportion of hours of the day that an animal is active) for five ungulate species (white-lipped peccary *Tayassu pecari*, collared peccary *Pecari tajacu*, red brocket deer *Mazama americana*, brown brocket deer *M. nemorivaga,* and tapir *Tapirus terrestris*) in four sites differing in the degree of access to hunters. To this end, in each of the four study areas, a grid of camera traps was placed within a polygon of approximately 100 km^2; traps operated continuously for three to four consecutive months. We recorded the date and time of detection for each species. Daily activity patterns and activity levels were estimated with kernel density analysis for circular data. Our work included a total of 9,506 effective trapping days for the four study sites, resulting in 1,063 separate records of the five ungulate species. In the four study areas, the brown brocket deer and the two species of peccaries concentrated their activity in daytime hours. The red brocket deer was most active in twilight hours, and the tapir was primarily nocturnal. At sites most accessible to hunters, the activity patterns of the collared peccary included a higher proportion of nighttime hours. The red brocket deer also seemed to increase the proportion of nighttime hours of its daily activity. The overall daily activity level was higher in the site with higher accessibility, but was statistically significant only for the collared peccary and the red brocket deer. Our findings include moderate statistically significant evidence suggesting that the access of hunters to the landscape influences the daily activity of ungulates in Yasuní. One species that is clearly affected by the access of hunters is the collared peccary, which becomes more nocturnal and increases its nighttime hours of activity when accessibility to hunters is higher. When our results are compared with other studies, it is evident that the species may display different behavioral responses to hunting, and that these responses may vary with the scale of analysis. This study was limited by sample sizes, which did not allow performing comprehensive analyses for all five species. To further understand the effects of hunting and other human activities on animal behavior, additional studies specifically designed for this purpose should be conducted.

Los ungulados constituyen uno de los grupos de mayor importancia en los ecosistemas terrestres de los trópicos. Adicionalmente, los ungulados son una fuente importante de proteína para los habitantes de los bosques tropicales y existen algunos estudios que evalúan el impacto de la cacería en el tamaño de las poblaciones de estas especies. Sin embargo, se conoce poco sobre otros efectos que la cacería puede tener en los ungulados. El propósito de este estudio fue evaluar el efecto de la accesibilidad de cazadores al paisaje en la actividad diaria de los ungulados en la Reserva de Biosfera Yasuní, un área natural protegida localizada en la región amazónica de Ecuador. Se comparó los patrones de actividad (*i. e.,* distribución de horas de actividad en el día) y niveles de actividad (*i. e.,* proporción de horas del día que un animal está activo) de cinco especies de ungulados (pecarí de labios blancos *Tayassu pecari*, pecarí de collar *Pecari tajacu*, venado colorado *Mazama americana*, venado marrón *Mazama nemorivaga* y tapir *Tapirus terrestris*) en cuatro sitios con diferente grado de accesibilidad de cazadores al paisaje. Para este propósito, en cada sitio se estableció una grilla de cámaras trampa en un polígono de aproximadamente 100 km^2, y que funcionó continuamente de tres a cuatro meses consecutivos. Para cada especie se registró su fecha y hora de detección. Los patrones y niveles de actividad diaria se estimaron por medio de un análisis de densidad de kernel para datos circulares. El esfuerzo total del presente trabajo fue de 9,506 días efectivos de muestreo entre los cuatro sitios de estudio que resultó en 1,063 registros independientes de las cinco especies de ungulados. En los cuatro sitios estudiados, el venado marrón y ambas especies de pecarí concentraron su actividad en la mañana. El venado colorado fue más activo en los crepúsculos y el tapir fue principalmente nocturno. En los sitios con mayor acceso de cazadores, el patrón de actividad del pecarí de collar incluyó una mayor proporción de horas de la noche. El venado colorado también pareció incrementar la proporción de horas nocturnas en su actividad diaria. En general, el nivel de actividad diaria fue más alto en el sitio de mayor acceso aunque estadísticamente significativo únicamente para el pecarí de collar y el venado colorado. Nuestro estudio encuentra pocas evidencias estadísticamente significativas de que la accesibilidad de cazadores al paisaje tiene un efecto en la actividad diaria de los ungulados en Yasuní. Una especie que muestra efectos claros es el pecarí de collar, que incrementa sus horas de actividad cuando la accesibilidad de cazadores al paisaje aumenta. Por medio de comparar nuestros resultados con otros estudios, observamos que la cacería puede tener efectos diferentes en el comportamiento de las especies, y que además, estos resultados pueden variar según la escala de análisis. Es importante notar que este estudio estuvo limitado por los tamaños de muestra que no permitieron realizar los mismos análisis para todas las especies. Para conocer a más profundidad los efectos de la cacería y otras actividades humanas en el comportamiento animal, sugerimos realizar más estudios específicamente diseñados para este propósito.

Key words: activity level; activity pattern; circadian activity; kernel analyses; *Mazama americana*; *Mazama nemorivaga*; *Pecari tajacu*; *Tapirus terrestris*; *Tayassu pecari*.

Introduction

Ungulates include the most hunted wildlife species by local inhabitants in tropical ecosystems (Robinson and Bennett 2000; Jerozolimski and Peres 2003; Milner-Gulland *et al.* 2003). In the Neotropics, the study of the impact of hunting on this group of animals has focused on the assessment of their populations, since the decrease in the number of individuals is a serious threat for exploited populations (*e. g*., Peres 1996; Bodmer *et al.* 1997; Hurtado-Gonzales and Bodmer 2004; Reyna-Hurtado and Tanner 2007). However, other aspects of the exploited species, including their behavior, are still little known. In animal behavior, daily activity is a key element which, for instance, has been used to explain the sympatry of close species that share similar trophic niches, or the relationships between predators and their prey (*e. g.,* Rivero *et al.* 2005; Harmsen *et al.* 2011).

The daily activity of organisms can be influenced by both physiological and environmental factors (*e. g*., habitat availability, presence of predators), including human activities (Kitchen *et al.* 2000; Foster and Kreitzman 2005). In the Netropics, daily activity patterns of ungulates have been described in several works (*e. g*., Carrillo *et al.* 2002; Noss *et al.* 2003; Gómez *et al.* 2005; Rivero *et al*. 2005; Tobler *et al.* 2009; Oliveira-Santos *et al.* 2010; Harmsen *et al*. 2011; Blake et al. 2012); however, the effect of human actions in this aspect of animal behavior has been little studied (*e. g.*, Di Bitetti *et al.* 2008). Previous studies indicate that hunting affects the daily activity of wild pigs *Sus scrofa* in Germany (Keuling *et al.* 2008). On the other hand, in Argentina it has been observed that the red brocket deer *Mazama americana* increases its peaks of activity in the nighttime hours in areas with higher hunting levels, probably to evade hunters (Di Bitetti *et al.* 2008).

The aim of this work was to evaluate the effect of accessibility of hunters to the landscape on the daily activity of ungulates in Yasuní Biosphere Reserve, located in the Ecuadorian Amazon where there are five sympatric species of ungulates (white-lipped peccary *Tayassu pecari*, collared peccary *Pecari tajacu*, red brocket deer *Mazama americana*, brown brocket deer *M. nemorivaga,* and tapir *Tapirus terrestris*). To this end, this study analyses the daily activity in four sites that differ in the degree of accessibility to hunters. In addition, the results of this work are compared with a similar work conducted at a finer spatial scale in one of the sites included in this study (Salvador 2015). Because of its size, Yasuní is the protected area with the greatest potential for the conservation of viable ungulate populations in Ecuador. In Yasuní, however, ungulates are heavily exploited by indigenous hunters or settlers who live within or around the protected area and that use bushmeat as the main protein source or as an economic resource through bushmeat trade (Suárez *et al.* 2009; Espinosa *et al.* 2014). Our expectation is that a deeper knowledge of the relationships between human activities, such as hunting, and aspects of animal behavior, including activity patterns and levels, will contribute to the management and conservation of the species studied.

Materials and Methods

Study area. Yasuní Biosphere Reserve (YBR), Ecuador, is formed by Yasuní National Park (1,000,000 ha) and the Waorani Ethnic Reserve (800,000 ha; Figure 1). In addition, YBR consists of a buffer area that includes a 10 km-wide strip around its northern, southern and western borders. Yasuní is a tropical rainforest ecosystem, with a mean annual precipitation of 3,000 mm and virtually no seasonality; there are no months with precipitation below 130 mm (Valencia *et al.* 2004).

Yasuní is inhabited mainly by indigenous groups that practice subsistence hunting. In the case of the Waorani (the main indigenous group that lives in Yasuní), hunting is conducted mainly in daylight hours; only 1.2 % of the hunting events take place after 16:00 hours (Lu 1999). The hunting sessions last an average of 8 hours, and hunters, mostly men, are usually accompanied by other men, their wives or children; hunting is practiced by solitary hunters 25% of the time (Lu 1999).

Sampling of animals. Ungulates were studied using camera traps in four sites with different degree of accessibility to hunters. A previous study in Yasuní shows that the most accessible sites (*i. e.,* the sites closest to villages, roads or navigable rivers), are those most intensively exploited by local hunters (Espinosa *et al.* 2014). The study sites are visited almost exclusively by local hunters, because accessibility to outsiders is very limited. The sites studied, from lower to higher degree of accessibility, were Lorocachi, Tiputini, Keweriono and Vía Maxus (Figure 1).

Lorocachi is a Kichwa community of approximately 120 inhabitants, located at the southern border of Yasuní, on the banks of the Curaray river. A 300-men military base is adjacent to Lorocachi. Reaching Lorocachi requires to travel by air; hunters move across the area on foot or by canoe along the Curaray river. The Kichwa community meets its protein demand through fishing, poultry breeding, and hunting. Hunting is managed by means of no-hunting zones and harvest quotas for some species such as the paujil (*Mitu salvini*), the Amazonian tapir and the white-lipped peccary (Vallejo-Real 2007). Our study site was located 3 to 21 km away from the Lorocachi community. The Amazon hunters walk a maximum distance of 8 to 9 km from access sources, such as houses, roads or rivers (Peres and Lake 2003; Espinosa *et al.* 2014). We estimated that about 70 to 80 % of our Lorocachi study area was not accessible to hunters. Hunting by military personnel is prohibited; the army gets supplies from the Ecuadorian Armed Forces.

The Tiputini site was located next to the Tiputini river, in the Yasuní northern border. It is a non-inhabited area that is visited occasionally by Waorani and Kichwa hunters from nearby communities (Figure 1). To reach this site, hunters must navigate along the Tiputini river for three to five hours in motorized canoes.

The Keweriono site was located in the vicinity of the Waorani of Keweriono (about 60 inhabitants) and Apaika (10 inhabitants) communities, located along the Shiripuno river and within an area corresponding to Waorani Territory, at the Yasuní western end. Apaika and Keweriono are located at 15 and 25 km from a road (Vía Auca), respectively and can be reached either by canoe or on foot. Waorani hunters have access to the entire study area, which has been hunted mainly for subsistence purposes since the creation of the Keweriono community in 1989 (Lu 1999; Mena-Valenzuela *et al.* 2000).

The Vía Maxus site was located in the vicinity of a road built by the Maxus oil company in the early 1990s. The Waorani settlements of Guiyero, Tiwe, Ganketa and Timpoka are located in the vicinity of this site and are home to approximately 70 inhabitants. Although the number of inhabitants is small, hunting in this area has been intense, since the local inhabitants have used wildlife as a source of income, trading substantial quantities of bushmeat in the local markets (Espinosa *et al.* 2014).

The sampling of animals was designed for a study on the jaguar (Espinosa 2012); however, the data obtained for ungulates show no biases that preclude the present analysis; there is no reason to believe that cameras influence the hours when an animal is either active or inactive. In each site, a quadrant including 23 to 26 sampling stations was set (Figure 1), which operated continuously for three to four consecutive months. Each station comprised two Leaf River™ C1-BU camera traps placed in front of one another and perpendicular to trails. The stations were separated by two to three km and covered a minimum convex polygon of approximately 100 km^2 at each site (Table 1). Sampling was carried out in the months with lower precipitation between December 2007 and November 2009 (Table 1).

Analysis of activity patterns and levels. The activity of organisms is divided into two components: activity pattern and activity level. The activity pattern describes the distribution of the activity of an organism throughout the day (*e. g.*, diurnal, nocturnal, cathemeral), and the activity level indicates the proportion of hours per day that an animal is active (*e. g.*, 0.5 corresponds to 12 hours of activity; Ridout and Linkie 2009; Rowcliffe 2015). Activity patterns and levels were estimated based on the date and time recorded for each snapshot captured by camera traps. All the analyses in this study included only records where the period between detections was equal to or longer than one hour for a given species in a given station; these records were considered independent events (Di Bitetti *et al.* 2008).

Daily activity patterns were estimated using the kernel density method, which is ideal for circular data (Schmid and Schmidt 2006; Ridout and Linkie 2009), using the 'overlap' package for R (Meredith and Ridout 2014). For each species, we estimated the overall activity patterns, that is, pooling the data of the four study sites for each species. In addition, for the collared peccary and the red brocket deer, we estimated site-specific activity patterns, since these

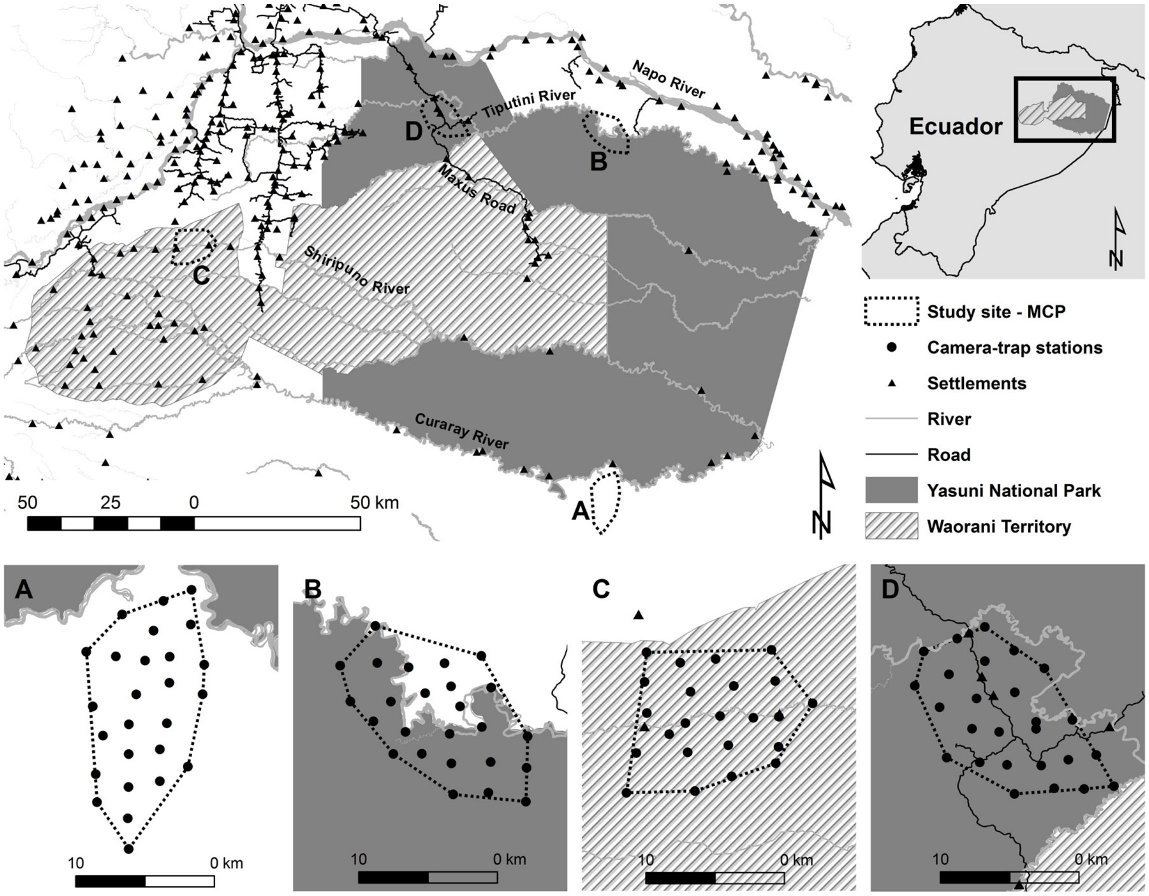

Figure 1. Study sites in the Yasuní Biosphere Reserve and its buffer zone. From lowest to highest accessibility to hunters: Lorocachi (A), Río Tiputini (B), Keweriono (C) and Vía Maxus (D).

were the only species with sufficient data for analysis at this scale. To evaluate the effect of accessibility to the landscape on the activity patterns of these two species, the coefficients of overlap Δ were compared between the four study sites. The coefficients of overlap are defined as the proportion of the area under the curve that is superimposed between the two activity patterns, where $\Delta = 0$ indicates no overlap (*e. g.*, a strictly nocturnal organism compared with a strictly diurnal one), and $\Delta = 1$ corresponds to a 100% overlap (*i. e.*, both activity patterns are identical; Meredith and Ridout 2016). We would expect a greater overlap of activity patterns between sites with similar degrees of accessibility (*i. e.*, hunting), and a lesser overlap between sites with different degrees of accessibility. We used the Δ_1 and Δ_4 overlap estimates, which are suitable when one of the patterns to be compared comes from a sample smaller than or greater than 75 records, respectively (Ridout and Linkie 2009; Meredith and Ridout 2016). The Δ_1 and Δ_4 confidence intervals were estimated with a bootstrap method, using 10,000 random resampling of data with replacement (Meredith and Ridout 2014). The coefficients of overlap were estimated with the 'overlap' package for R (Meredith and Ridout 2014), and were compared by means of a probabilistic bootstrap test (1,000 resampling events) using the 'activity' package for R (*compareCkern* function; Rowcliffe 2015).

Daily activity levels were estimated with the *fitact* function in the 'activity' package for R, which sets the hours, in radians, to a circular kernel density and estimates the activity level from this distribution (Rowcliffe 2015). For each of the five species recorded, daily activity levels were estimated both overall and for each particular site. For each of these estimates, we conducted a bootstrap with 1,000 resampling events; the statistical package provides measures of error (*i. e.,* standard error and 95 % confidence interval). To compare activity levels between sites, we used a Wald test run by the 'activity' package for R (*compareAct* function; Rowcliffe 2015).

Results

Data collection included 9,506 effective sampling days for the four study sites (Table 1). We obtained a total of 1,063 independent records of the five species of ungulates. Keweriono was the only site that did not record the five ungulate species present in Yasuní (Table 2).

Activity patterns and levels. The overall activity patterns and levels pool the data for each of the five species recorded in the four study sites. The white-lipped peccary, the collared peccary and the brown brocket deer showed a diurnal activity pattern, mostly between 06:00 h and 18:00 h (Figure 2). The red brocket deer showed two peaks of activity in the twilight, one at 06:00 h and the other at 18:00 h. The Amazonian tapir was nocturnal and showed two peaks of activity, one between 20:00 to 22:00 and another between 03:00 to 04:00 h (Figure 2). The overall activity levels were 0.44 (SE = 0.04) for the white-lipped peccary, 0.41 (SE = 0.02) for the collared peccary, 0.55 (SE = 0.05) for the red brocket deer, 0.43 (SE = 0.05) for the brown brocket deer, and 0.52 (SE = 0.04) for the Amazonian tapir.

Effect of landscape accessibility of hunters on daily activity patterns. The distribution of the activity pattern of the collared peccary in Tiputini showed two diurnal peaks of activity, at 07:00 h and 12:00 h, while in the other three sites the activity pattern had a unimodal distribution (Figure 3). The differences between the activity patterns of the collared peccary were significant ($P = 0.023$) only between Lorocachi and Vía Maxus — the two sites with the lowest and highest degree of accessibility, respectively. When compared with Lorocachi, it is noted that in Vía Maxus the collared peccary decreases the diurnal and increases the nighttime activity (Figure 3).

The activity patterns of the red brocket deer were similar between the most and least accessible sites, and there

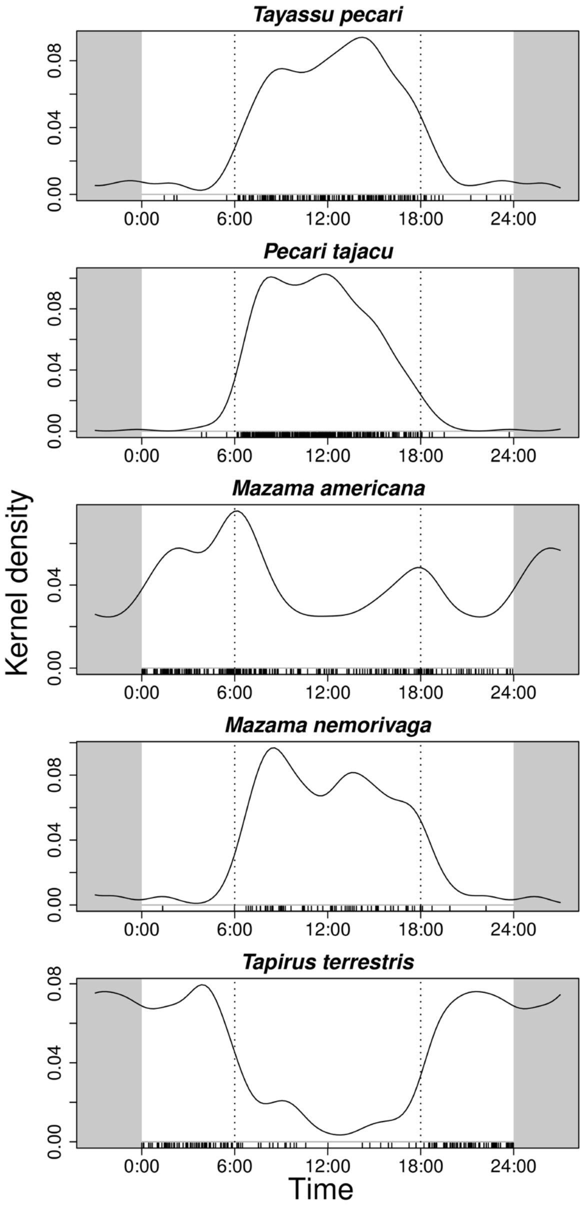

Figure 2. Overall activity patterns of ungulates in the Yasuní Biosphere Reserve. The strip at the base of the graphs represents the distribution of records for each species. The two parallel dotted lines represent approximate sunrise and sunset time in Ecuador, which vary approximately between 6:00 to 6:30 and 18:00 to 18:30 h, respectively, throughout the year.

were no significant differences in the coefficients of overlap between sites (Figure 4). However, it was observed that in the two most accessible sites (Keweriono and Vía Maxus) the twilight activity of the red brocket deer increases around noon; in addition, in the latter site, the 18:00 h peak of activity shifted to approximately 19:00 to 20:00 h (Figure 4).

Effect of landscape accessibility of hunters on daily activity levels. In the ungulate species analyzed, except for the brown brocket deer, the daily activity level was highest in Vía Maxus, which is the most accessible site for hunters (Figure 5). However, these differences are statistically significant only in two cases and considering an α of 10 %: the collared peccary between Lorocachi and Vía Maxus (Wald $\chi^2 = 2.85$, d. f. = 1, $P = 0.091$), and the red brocket deer between Tiputini and Vía Maxus (Wald $\chi^2 = 3.38$, d. f. = 1, $P = 0.066$; Table 3).

Discussion

The comparison of activity levels and patterns of species in sites with higher or lower accessibility levels by hunters showed few statistically significant differences, and these occurred in extreme cases. For instance, the activity pattern of the collared peccary was significantly different only between the most accessible site (Vía Maxus) and one of the two most remote sites (Lorocachi). Likewise, the activity level of the collared peccary was higher in Vía Maxus vs. Lorocachi, while the activity level of the red brocket deer was higher in Vía Maxus vs. Tiputini, the second most isolated site; these two results were significant at an α of 10 %. Therefore, it is evident that there are no solid results allowing to affirm that landscape accessibility by hunters affects the daily activity of organisms in general, although some species, such as the collared peccary, are seemingly affected by this factor.

To note, the changes in diurnal activity in the collared peccary and the red brocket deer showed an increase in nighttime activity in the most accessible sites. Similar patterns have been observed recently in a similar study in Vía Maxus, where the red brocket deer increases the proportion of hours of nighttime activity (Salvador 2015) in sites that are close to human settlements (*i. e.,* higher accessibility and hunting). The shift in the activity pattern toward nighttime in the presence of hunting has been observed previously in the red brocket deer, specifically in Argentina (Di Bitetti *et al.* 2008), as well as in other ungulate species, *e. g.*, the Mediterranean mouflon *Ovis gmelini musimon* (Marchand *et al.* 2014), and the sika *Cervus nippon* (van Doormaal *et al.* 2015). These observations support that both the collared peccary and the red brocket deer display plasticity to adapt their activity pattern in response to human intervention, which partially explains their permanence in sites like Vía Maxus in Yasuní, where hunting is intense, although other factors such as source-sink dynamics may be more important (Espinosa *et al.* 2014).

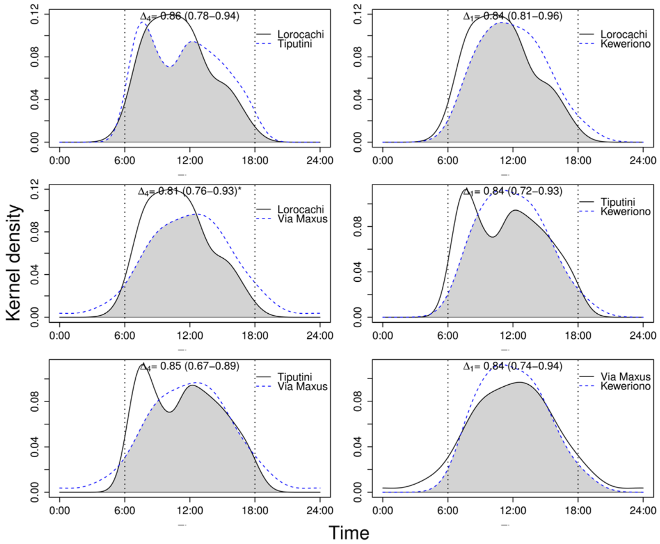

Figure 3. Overlap of the activity patterns of the collared peccary *Pecari tajacu* among the four study sites. The top of each chart details the coefficients of overlap, (95 % CI), for each comparison; *Significant difference (α < 5 %).

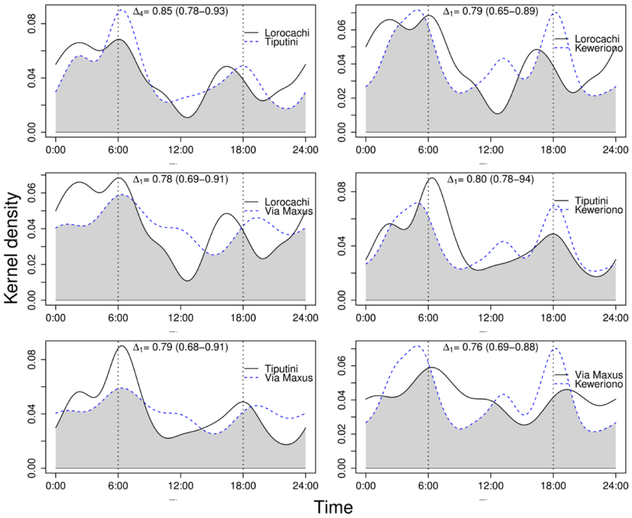

Figure 4. Overlap of the activity patterns of the red brocket deer *Mazama americana* among the four study sites. The top of each chart details the coefficients of overlap, (95% CI), for each comparison; no case yielded significant differences between Δ estimates.

Although there were virtually no significant differences, it is interesting to note a trend toward a higher activity level in the most accessible site (Vía Maxus) in four of the five species analyzed: tapir, white-lipped peccary, collared peccary

	Lorocachi	Tiputini	Keweriono	Vía Maxus
Camera trap stations	26	25	23	26
Installation of the first camara trap station	07/11/2008	11/20/2008	08/05/2009	11/24/2007
Removal of the last camara trap station	10/24/2008	03/19/2009	11/15/2009	03/09/2008
Effective trap-days	2458	2410	2132	2506
Minimum convex polygon of stations (km²)	110	110	106	104

Table 1. Sampling effort with camera traps in four sites across Yasuní Biosphere Reserve, Ecuador. The sites, ranked from lowest to highest accessibility to hunters, are: Lorocachi, Tiputini, Keweriono and Vía Maxus.

Table 2. Ungulate species recorded by camera traps in four sites across Yasuní Biosphere Reserve, Ecuador. The sites, ranked from lowest to highest accessibility to hunters, are: Lorocachi, Tiputini, Keweriono and Vía Maxus.

	Lorocachi	Tiputini	Keweriono	Vía Maxus	Total
Tapirus terrestris	50	80	6	33	169
Tayassu pecari	21	152	0	7	180
Pecari tajacu	121	129	41	76	367
Mazama americana	99	105	40	27	271
Mazama nemorivaga	17	44	0	15	76

and red brocket deer. This finding seemingly opposes what we might intuitively expect, because more active individuals would be more exposed to hunting. In a study at a finer scale in Vía Maxus, Salvador (2015) reports a higher activity level of the tapir in areas adjacent to Waorani settlements, similar to the observations in this study (*i. e.,* higher activity levels in more accessible sites). However, Salvador (2015) also notes that the activity of the white-lipped peccary and the red brocket deer was significantly higher in sites further away from the road or Waorani settlements, which are visited less frequently by local hunters (Espinosa *et al.* 2014). These seemingly contradictory observations indicate differential responses of species to disturbance, and may vary according to the scale of analysis.

An explanation for the increase in activity of ungulates in places more accessible to hunters is that, in addition to the time required for foraging, individuals need to spend time escaping from hunters or moving to safer places. It is well known that ungulate populations subjected to hunting pressure display a higher escape response versus populations in areas with no hunting pressure (Stankowich 2008). For example, it has been documented that hunting and other human activities lead to an increase in the daily movement of the American bison *Bison bison* (Fortin and Andruskiw 2003), and an increase in the level of vigilance of the red deer *Cervus elaphus* (Jayakody *et al.* 2008) and the European roe deer *Capreolus capreolus* (Benhaiem *et al.* 2008). However, little is known about the escape responses of Neotropical ungulates to the various disturbances caused by human activities (*e. g.,* hunting, presence of domestic animals, and recreational activities, among others).

Animals can respond to hunting in manners that resemble those observed in relation to their natural predators (Frid and Dill 2002). A common behavioral response of prey to the risk of predation is to avoid high-risk areas where predators or hunters are usually abundant. Therefore, human hunters can force prey to move to safer habitats, causing physiological stress, escape behaviors and alteration of the rhythms of activity (Frid and Dill 2002; Crosmary *et al.* 2012; Matassa and Trussell 2014). These behavioral responses have been reported in a number of organisms, ranging from aquatic birds (Fox and Madsen 1997) to large ungulates (Stankowich 2008). In the Neotropics, we have significant information related to the activity patterns of ungulates (*e. g.,* Carrillo *et al.* 2002; Noss *et al.* 2003; Gómez *et al.* 2005; Rivero *et al.* 2005; Tobler *et al.* 2009; Oliveira-Santos *et al.* 2010; Harmsen *et al.* 2011; Blake *et al.* 2012). However, there are still scarce studies to better understand the effects of anthropic actions on the daily activity of these organisms.

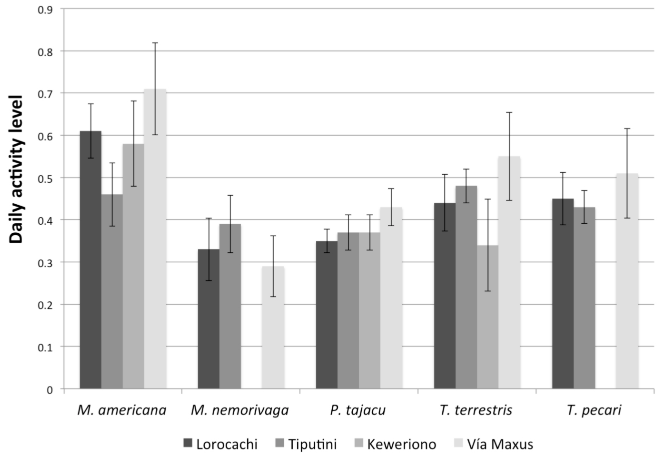

Figure 5. Daily activity level (*i. e.,* proportion of hours per day that an animal is active) of ungulates across the four study sites in Yasuní; error bars represent the standard error.

Table 3. Absolute differences in the daily activity level (*i. e.,* proportion of hours per day that an animal is active) of ungulates across the four study sites; standard errors are shown in parenthesis.

		Tiputini	Keweriono	Vía Maxus
Mazama americana	Lorocachi	0.147 (0.097)	0.028 (0.111)	0.097 (0.126)
	Tiputini	-	0.119 (0.118)	0.244 (0.133)*
	Keweriono	-	-	0.125 (0.143)
Mazama nemorivaga	Lorocachi	0.063 (0.100)	NA	0.037 (0.103)
	Tiputini	-	NA	0.100 (0.099)
	Keweriono	-	-	NA
Pecari tajacu	Lorocachi	0.022 (0.049)	0.023 (0.052)	0.083 (0.049)*
	Tiputini	-	0.002 (0.060)	0.061 (0.056)
	Keweriono	-	-	0.060 (0.059)
Tapirus terrestris	Lorocachi	0.043 (0.078)	0.091 (0.128)	0.116 (0.124)
	Tiputini	-	0.132 (0.116)	0.075 (0.112)
	Keweriono	-	-	0.207 (0.151)
Tayassu pecari	Lorocachi	0.016 (0.073)	NA	0.062 (0.122)
	Tiputini	-	NA	0.078 (0.122)
	Keweriono	-	-	NA

*Significant difference (α < 10 %); Not Available (NA): *T. pecari* and *M. nemorivaga* were not registered in Keweriono..

This study shows some evidence of the effects of the accessibility of hunters to the landscape on the daily activity of ungulates that inhabit Yasuní. However, further information is needed to draw clearer conclusions, since the limited data available did not allow to perform the same analysis for all the species studied. This lack of information for some species is linked to hunting, and demonstrates the negative effect of this activity on animal populations when management is inadequate (Reyna-Hurtado and Tanner 2007). For example, in Keweriono the white-lipped peccary, one of the species most heavily hunted by the Waorani, has not been observed over the past 20 to 30 years (Mena-Valenzuela *et al*. 2000, Espinosa *et al*. 2014).

The comparison of our results with those obtained in a separate study (Salvador 2015) revealed that in one of the sites included in this study (Vía Maxus) the type of behavioral response of ungulates to hunting may vary between species and may change according to the scale of analysis. The knowledge of the factors that influence animal behavior is relevant to understand how species adapt and persist in their habitats, thus making it necessary to evaluate the impacts of potential management alternatives, such as hunting or tourist activities. We believe it is necessary to expand the research with studies specifically designed to address questions related to animal behavior.

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Literature cited

Blake, J. G., D. Mosquera, B. Loiselle, K. Swing, J. Guerra, and D. Romo. 2012. Temporal activity patterns of terrestrial mammals in lowland rainforest of Eastern Ecuador. Ecotropica 18:137–146.

Benhaiem, S., M. Delon, B. Lourtet, B. Cargnelutti, S. Aulagnier, A. J. M. Hewison, N. Morellet, and H. Verheyden. 2008. Hunting increases vigilance levels in roe deer and modifies feeding site selection. Animal Behaviour 76:611–618.

Bodmer, R. E., J. F. Eisenberg, and K. H. Redford. 1997. Hunting and the likelihood of extinction of Amazonian mammals. Conservation Biology 11:460–466.

Carrillo, E., J. C. Saenz, and T. K. Fuller. 2002. Movements and activities of white-lipped peccaries in Corcovado National Park, Costa Rica. Biological Conservation 108:317–324.

Crosmary, W.-G., M. Valeix, H. Fritz, H. Madzikanda, and S. D. Côté. 2012. African ungulates and their drinking problems: hunting and predation risks constrain access to water. Animal Behaviour 83:145–153.

Di Bitetti, M. S., A. Paviolo, C. A. Ferrari, C. De Angelo, and Y. Di Blanco. 2008. Differential responses to hunting in two sympatric species of brocket deer (*Mazama americana* and *M. nana*). Biotropica 40:636–645.

Espinosa, S. 2012. Road development, bushmeat extraction and jaguar conservation in Yasuní Biosphere Reserve - Ecuador. Tesis de Doctorado. University of Florida. Gainesville, U. S. A.

Espinosa, S., L. C. Branch, and R. Cueva. 2014. Road development and the geography of hunting by an Amazonian indigenous group: consequences for wildlife conservation. PLoS ONE 9(12):e114916. doi:10.1371/journal.pone.0114916

Fortin, D., and M. Andruskiw. 2003. Behavioral Response of Free-Ranging Bison to Human Disturbance. Wildlife Society Bulletin 31:804–813.

Foster, R. G., and L. Kreitzman. 2005. Rhythms of life: the biological clocks that control the daily lives of every living thing. Yale University Press. New Haven, U. S. A.

Fox, A. D., and J. Madsen. 1997**.** Behavioural and distributional effects of hunting disturbance on waterbirds in Europe: implications for refuge design. Journal of Applied Ecology 34:1–13.

Frid, A., and L. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. Conservation Ecology 6:11. URL: http://www.consecol.org/vol6/iss1/art11

Gómez, H., R. B. Wallace, G. Ayala, and R. Tejada. 2005. Dry season activity periods of some Amazonian mammals. Studies on Neotropical Fauna and Environment 40:91–95.

Harmsen, B. J., R. J. Fostera, S. C. Silver, L. E. T. Ostrod, and C. P. Doncaster. 2011. Jaguar and puma activity patterns in relation to their main prey. Mammalian Biology 76:320–324.

Hurtado-Gonzales, J. L., and R. E. Bodmer. 2004. Assessing the sustainability of brocket deer hunting in the Tamshiyacu-Tahuayo Communal Reserve, northeastern Peru. Biological Conservation 116:1–7.

Jayakody, S., A. M. Sibbald, I. J. Gordon, and X. Lambin. 2008. Red deer *Cervus elaphus* vigilance behaviour differs with habitat and type of human disturbance. Wildlife Biology 14:81–91.

Jerozolimski, A., and C. A. Peres. 2003. Bringing home the biggest bacon: A cross-site analysis of the structure of hunter-kill profiles in Neotropical forests. Biological Conservation 111:415–425.

Keuling, O., N. Stier, and M. Roth. 2008. How does hunting influence activity and spatial usage in wild boar *Sus scrofa* L.? European Journal of Wildlife Research 54:729–737.

Kitchen, A. M., E. M. Gese, and E. R. Schauster. 2000. Changes in coyote activity patterns due to reduced exposure to human persecution. Canadian Journal of Zoology 78:853–857.

Lu, F. 1999. Changes in subsistence patterns and resource use of the Huaorani indians in the Ecuadorian Amazon. Tesis de Doctorado. University of North Carolina, Chapel Hill, NC.

Marchand, P., M. Garel, G. Bourgoin, D. Dubray, D. Maillard, and A. Loison. 2014. Impacts of tourism and hunting on a large herbivore's spatio-temporal behavior in and around a French protected area. Biological Conservation 177:1–11.

Matassa, C. M., and G. C. Trussell. 2014. Prey state shapes the effects of temporal variation in predation risk. Proceedings of the Royal Society B 281:20141952.

Mena-Valenzuela, P., J. R. Stallings, J. Regalado, and R. Cueva. 2000. The sustainability of current hunting practices by the

Huaorani. Pp. 57–78, in Hunting for sustainability in tropical forests (Robinson, J. G., and E. L. Bennett, eds.). Columbia University Press. New York, U. S. A.

Meredith, M., and M. Ridout. 2014. overlap: Estimates of coefficient of overlapping for animal activity patterns R package version 0.2.3. Accesible en: https://cran.r-project.org

Meredith, M., and M. Ridout. 2016. Overview of the overlap package. Accesible en: https://cran.r-project.org

Milner-Gulland, E. J., E. L. Bennett, K. Abernethy, M. Bakarr, R. Bodmer, S. J. Brashares, G. Cowlishaw, P. Elkan, H. Eves, J. Fa, C. A. Peres, C. Roberts, J. Robinson, M. Rowcliffe, and D. Wilkie. 2003. Wild meat: The big picture. Trends in Ecology and Evolution 18:351–357.

Noss, A. J., R. L. Cuéllar, J. Barrientos, L. Maffei, E. Cuéllar, R. Arispe, D. Rúmiz, and K. Rivero. 2003. A camera trapping and radio telemetry study of lowland tapir (*Tapirus terrestris*) in Bolivian dry forest. Tapir Conservation-Newsletter of the IUCN/SSC Tapir Specialist Group 12:24–32.

Oliveira-Santos, L. G. R., , L. C. P. Machado-Filho, M. A. Tortato, and L. Brusius. 2010. Influence of extrinsic variables on activity and habitat selection of lowland tapirs (*Tapirus terrestris*) in the coastal sand plain shrub, southern Brazil. Mammalian Biology 75:219–226.

Peres, C. A. 1996. Population status of the white-lipped *Tayassu pecari* and collared peccaries *T. tajacu* in hunted and unhunted Amazonian forests. Biological Conservation 77:115–123.

Peres, C. A., and I. R. Lake. 2003. Extent of nontimber resource extraction in tropical forests: accessibility to game vertebrates by hunters in the Amazon basin. Conservation Biology 17:521–535.

Reyna-Hurtado, R., and G. W. Tanner. 2007. Ungulate relative abundance in hunted and non-hunted sites in Calakmul Forest (Southern Mexico). Biodiversity and Conservation 16:743–756.

Ridout, M. S., and M. Linkie. 2009. Estimating overlap of daily activity patterns from camera trap data. Journal of Agricultural, Biological and Environmental Statistics 14:322–337.

Rivero, K., D. I. Rumiz, and A. B. Taber. 2005. Differential habitat use by two sympatric brocket deer species (*Mazama americana* and *M. gouazoubira*) in a seasonal Chiquitano forest of Bolivia. Mammalia 69:169–183.

Robinson, J. G., and E. L. Bennett. 2000. Carrying capacity limits to sustainable hunting in tropical forests. Pp. 13-30 in Hunting for sustainability in tropical forests (Robinson, J. G., and E. L. Bennett, eds.). Columbia University Press, New York.

Rowcliffe, M. 2015. R Package 'activity'. Accesible en: https://cran.r-project.org

Schmid, F., and A. Schmidt. 2006. Nonparametric estimation of the coefficient of overlapping - Theory and empirical application. Computational Statistics and Data Analysis 50:1583–1596.

Salvador, J. 2015. Effects of human disturbance on occurrence patterns and behavior of terrestrial mammals in eastern Ecuador. Tesis de Maestría. University of Florida. Gainesville, U. S. A.

Stankowich, T. 2008. Ungulate flight responses to human disturbance: a review and meta-analysis. Biological Conservation 141:2159–2173.

Suárez, E., M. Morales, R. Cueva, V. Utreras Bucheli, G. Zapata-Ríos, E. Toral, J. Torres, W. Prado, and J. Vargas Olalla. 2009. Oil industry, wild meat trade and roads: indirect effects of oil extraction activities in a protected area in north-eastern Ecuador. Animal Conservation 12:364–373.

Tobler, M. W., S. E. Carrillo-Percastegui, and G. Powell. 2009. Habitat use, activity patterns and use of mineral licks by five species of ungulate in south-eastern Peru. Journal of Tropical Ecology 25:261–270.

Valencia, R., R. B. Foster, G. Villa, R. Condit, J. C. Svenning, C. Hernandez, K. Romoleroux, E. Losos, E. Magard, and H. Balslev. 2004. Tree species distributions and local habitat variation in the Amazon: large forest plot in eastern Ecuador. Journal of Ecology 92:214–229.

Vallejo-Real, I. 2007. Experiencias etnoambientales, etnozoneamiento y derechos territoriales en la amazonía centro. Pp. 507-541, in II Congreso Ecuatoriano de Antropología y Arqueolgía Tomo 2. (F. García, ed.). Ediciones Abya-Yala. Quito, Ecuador.

van Doormaal, N., H. Ohashi, S. Koike, and K. Kaji. 2015. Influence of human activities on the activity patterns of Japanese sika deer (*Cervus nippon*) and wild boar (*Sus scrofa*) in Central Japan. European Journal of Wildlife Research 61:517–527.

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Morphometric patterns in assemblages of Cricetid rodents from the Central and Western Cordilleras of Colombia

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The mechanisms that mediate the formation and coexistence of species assemblages have been a historical issue in evolutionary ecology, raising the question of whether these assemblages are shaped at random or are influenced by biotic and abiotic processes. An increasingly popular hypothesis points out that certain patterns or "assemblage rules" determine coexistence patterns within assemblages at a regional or continental scale. Thus, morphological and ecological similarities could influence the degree and intensity of competition between species. Considering the morphology of organisms within an environmental framework, we could assess the morphology and understand the ecological role of a given species within the assemblage. This study assesses the similarities and differences of Andean rodents within local assemblages through a Principal Component Analysis (PCA), using craniodental characters of these species to establish whether the relationships between morphometry and coexistence provide evidence to explain assemblage structure patterns. We measured rodent specimens deposited in the Colección Teriológica of the University of Antioquia, collected from the Western and Central cordilleras of Colombia. We recorded 15 craniodental variables from all specimens, which were analyzed with a PCA to search for a general organization pattern within assemblages. Afterwards, we plotted the scores for principal components 1 and 2 to evidence the separation or clustering of specimens in an Euclidean space. We recorded 424 specimens from 10 genera and 18 species of the family Cricetidae, with the genera *Nephelomys* and *Thomasomys* showing the largest number of specimens. In the overall PCA, the first three components account for 85.1 % of the variation, with 63.9 % for PC1. The variables with the greatest contributions to PC1 were ZPW, AW and MFW; to PC2, IFL, ZPW and MFW; and to PC3, IFL, OL and ML. We detected some overlapping and scattering patterns among species at the morphospace defined by PC1 and PC2. We recovered an arrangement of species that shows differences in size and shape between them (as a function of their morphology), as evidenced in the scatter plots for the regional and local analyses. Besides, we did not find a general pattern for the load of variables, although some of these accounted for a larger part of the variation in the overall and local analyses (ZPW, MFW, IFL, ML and RL), indicating the segregation among species. Although the local analyses revealed a similar pattern with these loads changing from site to site, five variables account for the largest variation, what we interpret as a key role to determine the morphometric and/or ecological segregation among species. We believe this first approximation shows the value of ecomorphological studies in understanding patterns of diversity and geographic replacement of species; these patterns should be integrated with analyses of ecological aspects to understand the coexistence of species within local assemblages.

Los mecanismos que intervienen en la formación y coexistencia de ensamblajes de especies han sido un tema histórico en ecología evolutiva, de allí surge la pregunta si los ensamblajes de especies se forman aleatoriamente o si son influenciados por procesos bióticos y abióticos. Una hipótesis de popularidad creciente indica que los patrones de coexistencia en un ensamblaje, tanto a nivel regional como continental, son determinados por ciertos patrones o "reglas de ensamblaje". Así, el grado e intensidad de la competencia entre especies pueden ser influenciados por su similitud morfológica y ecológica. Considerando la morfología de los organismos formando parte de un esquema ambiental podríamos lograr describir dicha morfología y entender la función ecológica de dicha especie al interior del ensamblaje. Este estudio evalúa las similitudes y diferencias en ensamblajes locales de roedores andinos por medio de Análisis de Componentes Principales (ACP), utilizando aspectos de la morfología cráneo-dental de las especies para establecer si las relaciones entre la morfometría y la coexistencia proporcionan evidencia de patrones de estructuración de los ensamblajes. Se midieron especímenes de la Colección Teriológica de la Universidad de Antioquia, provenientes de las Cordilleras Central y Occidental Colombianas. Se usaron 15 medidas craneales para todos los especímenes, realizando luego un ACP para explorar la existencia de un patrón de organización general a nivel de ensamblajes. Por último, se representaron los valores de los componentes principales 1 y 2 en gráficas de dispersión para visualizar la separación y/o aglomeración de especímenes en el espacio euclidiano. Se registraron un total de 424 especímenes pertenecientes a 10 géneros y 18 especies de la familia Cricetidae, con el mayor número de individuos en los géneros *Nephelomys* y *Thomasomys*. En el ACP total los primeros tres componentes contienen 85.1 % de la variación, con 63.9 % para el CP1. Las variables que más aportan al CP1 son ZPW, AW y MFW; al CP2, IFL, ZPW and MFW y al CP3, IFL, OL and ML. Se observan algunos patrones de superposición y dispersión de especies en el morfoespacio definido por el CP1 y CP2. Se logró apreciar un arreglo de especies en el cual se encuentran diferencias en tamaño y forma entre las especies (en función de su morfología), esto se evidencia en las gráficas de dispersión tanto del análisis regional como de los análisis locales. Además, no se encontró un patrón definido en las cargas de las variables, aunque algunas aportaron mayor variación en el análisis total y en los individuales (ZPW, MFW, IFL, ML y RL), determinando la segregación entre especies. A pesar de que en los análisis de cada localidad estos aportes se reparten de forma diferente, cinco variables están aportando la mayor variación, por lo que se infiere que serían claves en determinar la separación morfométrica y/o ecológica de las especies. Finalmente, esta primera aproximación muestra la utilidad de estudios ecomorfológicos para entender patrones de diversidad y reemplazo geográfico de especies, los cuales deberían integrarse con análisis de aspectos ecológicos para interpretar su coexistencia en un ensamblaje local.

Key words: Andean rodents; assemblage rules; evolutionary ecology; morphometrics; Principal Component Analysis.

Introduction

The processes that govern the existence and formation of species assemblages have been a recurrent discussion topic in evolutionary ecology (Diamond 1975; Connor and Simberloff 1979; Bowers and Brown 1982, Gotelli and Ellison 2002), raising the questiont of whether the species assemblages (in a broad sense, a phylogenetically related group within a community; see Fauth *et al.* 1996) are formed at random, or, on the contrary, are determined by biotic and abiotic processes (Arita 1997; Adams 2007). Various authors (Diamond 1975; Bowers and Brown 1982; Patterson 1999; Adams 2007; Gotelli and Ellison 2002) have suggested that the patterns of species coexistence within an assemblage, at the regional and continental levels, do not occur at random but are determined by certain general patterns or "assemblage rules". These rules would favor the co-occurrence of certain species at the local level, or would eventually determine the morphology (for example, the arrangement of sizes) through interspecific competition dynamics (Willig and Moulton 1989; Gotelli and Ellison 2002). As a result, species within some highly diverse communities will display a relatively uniform organization across a size gradient (Willig 1986; Arita 1997; Adams 2007); as a result, morphologically similar species within a trophic guild are unlikely to occupy the same habitat (Bowers and Brown 1982).

As suggested in other studies, interspecific competition may affect morphological patterns through changes in either the organization of sizes or the adjustment of sizes (Bowers and Brown 1982; Willig and Moulton 1989). In the former case, the probability of persistence of a species within an assemblage decreases by the presence of morphologically similar species, while the latter refers to evolutionary changes in a morphological feature of the involved species to minimize competition (Willig and Moulton 1989). In both cases, an in-depth understanding of the role of competition has been restrained by various methodological issues, in particular the determination of the belonging to ecological guilds and the construction of statistically null assemblages (Arita 1997). For example, it has been indicated that the organization or adjustment of sizes could only act at the assemblage level when competition is sufficiently intense and prevalent at the local level (Willig and Moulton 1989).

If the morphology of an organism is considered as part of an environmental mold, we could describe such morphology and understand the ecological role of this species within the assemblage (Ricklefs and Travis 1980; Willig 1986). Multivariate analyses have been used to describe and compare the spatial clustering of species, by representing these within a hyperdimensional Euclidean space, to estimate the ecological structure within the assemblage (Findley 1975; Ricklefs and Travis 1980; Freeman 1981; Willig 1986; James and McCulloch 1990; Arita 1997; Peres-Neto *et al.* 2003). In general, morphometric characters are usually easier to obtain (often from museum specimens or even from publications), simple to estimate, highly replicable, independent of the structure of the habitat, and adequately correlated with resource use (Pizzimenti and De Salle 1980; Ricklefs and Travis 1980; Freeman 1998). In addition, if morphology is not directly related to ecology, multivariate analyses can unveil patterns that are explained based on a theoretical, ecological and evolutionary context (Ricklefs and Travis 1980; Willig 1986).

In the present study, we used a Principal Components Analysis (PCA) to determine the relative importance of variables with respect to each component (Crisci and Lopez-A 1983; James and McCulloch 1990), and use it as an approximate description of the relationships between the units of study (Peres-Neto *et al.* 2003), or between their ecological roles, if these are determined by the original variables (Pizzimenti and De Salle 1980; Ricklefs and Travis 1980). If such a pattern does exist and is adequately represented in the variables chosen, the major components of the regional and local analyses would be expected to show similar loads for most variables (Ricklefs and Travis 1980; Peres-Neto *et al.* 2003).

To assess these patterns, this study focuses on cricetid rodents of the Western, Central and Eastern cordilleras of Colombia. Previous studies (Lopez-Arevalo *et al.* 1993; Gómez-Valencia 2006; Muñoz-Saba *et al.* 2000; Otarola 2003; Sánchez *et al.* 2004; Viancha-Sánchez *et al.* 2012; Sánchez-Giraldo and Díaz-Nieto 2015) agree that the local richness of rodents reaches an average between 9 and 11 species in 8 to 10 genera, and that composition varies according to elevation and geographic region. At the regional scale, more intensive studies in the Andes of Venezuela (Soriano *et al.* 1999) and Ecuador (Voss 2003) report 10 and 9 genera of rodents, respectively. Although these studies suggest a regional pattern in these assemblages, the morphometric relationships between organisms within these are not analyzed, which would be key in the process of organization and maintenance of assemblages at the local level (Pizzimenti and De Salle 1980; Ricklefs and Travis 1980; Arita 1997). The objective of this study is to evaluate the similarities and differences between local rodent assemblages from morphometric analyses, using craniodental variables of specimens to infer potential patterns of ecological interrelationship between species. In this way, it could be established whether the relationships between morphometry and coexistence provide evidence of assemblage structuring patterns, for example through a regular arrangement of sizes or shapes among species (Pizzimenti and De Salle 1980; Ricklefs and Travis 1980; Arita 1997).

Materials and Methods

Data collection. We measured specimens deposited in the Colección Teriológica of the University of Antioquia, Colombia, collected from the Andean region (Central and Western Cordilleras), between 2002 and 2014. Some localities were pooled together to avoid losing information for specimens whose specific localities contained low representativeness in terms of number of species. To this end, we took into account that the pooled localities belong politically and/or geographically to the same region, from the 2008 map of the Antioquia regions (available at http://www.zonu.com/detail/2011-08-23-14446/Regiones--de-Antioquia-2008.html), thereby gathering as much information as possible (Table 1). For example, Bello and Girardota were pooled together (Aburrá Norte), while Jardín-Támesis and La Mesenia (both in the Municipality of Jardín) were kept separated for being located in different mountain ranges. In this way, the analyses are based on these regional units (Figure 1).

Taxonomic identification was performed using keys (Weksler and Percequillo 2011; Patton *et al.* 2015), descriptions (Voss *et al.* 2002; Pacheco 2003; Percequillo 2003; Voss 2003; Weksler 2006) and reference material from the same collection and the Field Museum of Natural History (Chicago, USA).

Morphological and Morphometric Analyses. We recorded 15 homolog cranial measurements for all specimens (adult males and females), following the specifications of Patton *et al.* (2000) and Voss *et al.* (2001). These measures sought to highlight morpho-functional aspects, for example as regard chewing, or resource selection (see Pizzimenti and De Salle 1980; Giménez and Giannini 2011). The measures employed were: condyle-incisor length (CIL), zygomatic width (ZW), mastoid width (MW), minimum interorbital constriction (MIC/LIB), rostral length (RL), nasal length (NL), rostral width (RW), orbital length (OL), diastema length (DL), molar-row length (ML/LM), incisive-foramen length (IFL), palatal bridge length (PBL), alveolar width (AW), mesopterygoid fossa width (MFW), and zygomatic plate width (ZPW/BZP). Measurements were taken with an electronic caliper to the nearest 0.01 mm, and using a stereoscopic microscope in the case of measures requiring greater precision.

Statistical Analyses The original data were log-transformed (log10; using the program PAST) to reduce biases associated with the different magnitudes of variables, approaching a normal distribution of the data (Ricklefs and Travis 1980; Jackson 1993); then a variance-covariance matrix was obtained (James and McCulloch 1990). This matrix was used to conduct a Principal Components Analysis (PCA) to elucidate the variability of variables (characters), measured in terms of their factorial coefficients (loads). In this analysis, eigenvalues represent the sum of the variances of variables for each component, used for determining which components are more important (Jackson 1993); the components with the largest eigenvalues were used to be represented graphically.

In this way, the PCA was used as a screening tool (Norman and Streiner 1996) for the set of all localities (regional analysis), as well as for some localities evaluated individually (local analyses), to allow a comparison between components and their basic parameters, such as eigenvalues, percentages of variation and factorial coefficients. In order to confirm the reliability when choosing the appropriate components in the overall PCA, a 'bootstrap' resampling of 1000 repetitions was conducted (Jackson 1993; Peres-Neto *et al.* 2003). In addition, it is also expected to organize the variation related to any individual variable. That is, if two or more variables are summarized by the same component, this will indicate that these share similar co-variation patterns, leading to a better interpretation of the relationship (Peres-Neto *et al.* 2003). Finally, the values of the first principal compo-

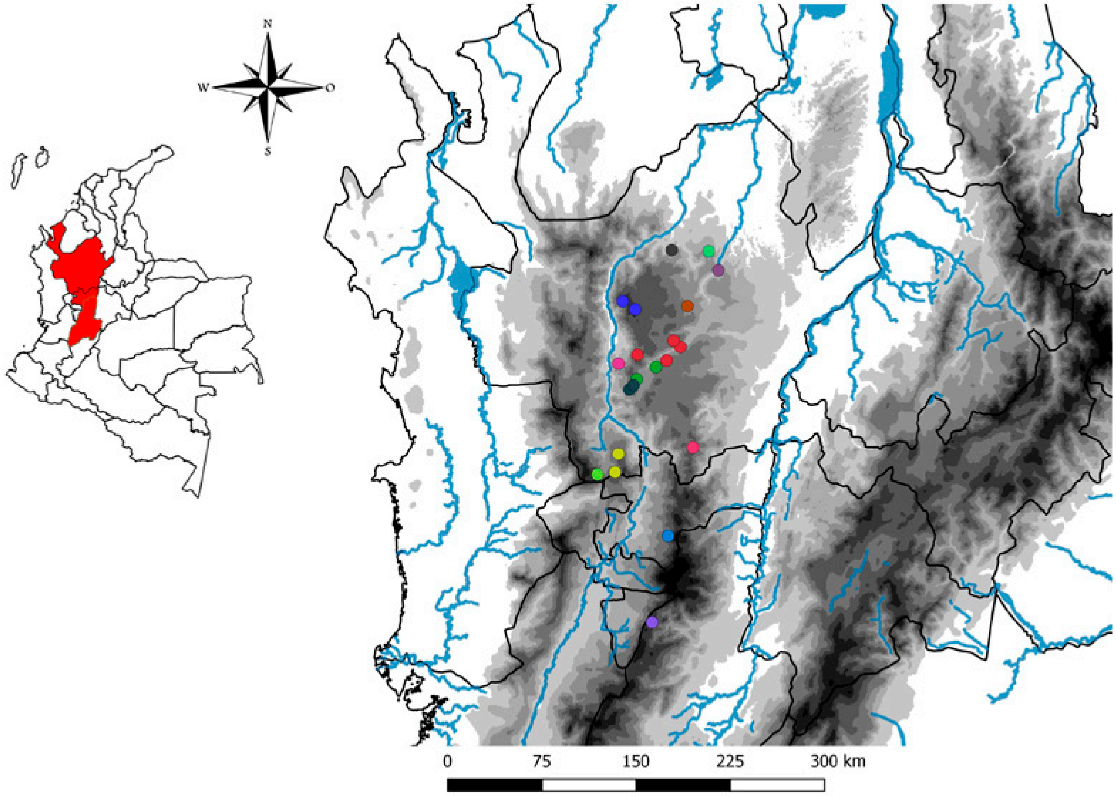

Figure 1. Map of the municipalities in the departments of Antioquia, Caldas and Tolima that included sampling localities for the specimens used in morphometric analyses.

Table 1. Rodent species included in the analysis with their respective numbers of localities and specimens.

SPECIES	# LOCALITIES	# SPECIMENS
Akodon affinis	8	29
Chilomys instans	4	11
Handleyomys alfaroi	1	2
Handleyomys fuscatus	2	30
Handleyomys intectus	4	38
Melanomys caliginosus	8	37
Microryzomys minutus	5	6
Neacomys tenuipes	5	9
Nephelomys childi	1	15
Nephelomys pectoralis	12	119
Reithrodontomys mexicanus	5	11
Rhipidomys latimanus	7	19
Thomasomys baeops	2	5
Thomasomys cinereiventer	1	4
Thomasomys cinnameus	2	9
Thomasomys contradictus	6	57
Thomasomys nicefori	4	21
Thomasomys popayanus	2	2
TOTAL	**18**	**424**

nents (which represent the greatest variance of the data) are shown in scatter plots obtained with the PAST program (Paleontological Statistics version 3.04; Hammer *et al.* 2001).

Results

Number of species and individuals per locality. A total of 424 specimens of Andean rodents were recorded, belonging to 10 genera and 18 species of the family Cricetidae (Sigmodontinae): *Akodon, Chilomys, Handleyomys, Melanomys, Microryzomys, Neacomys, Nephelomys, Reithrodontomys, Rhipidomys* and *Thomasomys* (Figure 2), of which *Thomasomys*, *Handleyomys* and *Nephelomys* were the most diverse ones, with six, three and two species, respectively, while the rest recorded a single species each. The genus with the largest number of individuals was *Nephelomys* with 134 specimens, followed by *Thomasomys* with 98 specimens. The least represented genera were *Neacomys* and *Microryzomys,* with 9 and 6 specimens, respectively (Table 1).

The specimens analyzed were obtained from different localities in the departments of Antioquia, Caldas and Tolima (Table 2), Antioquía being the most important one for its larger number of localities. On the other hand, the comparisons between assemblages were conducted using five localities that showed a high representativeness of individuals and species (see Table 2), as the availability of individuals was restricted in some localities where samples were not rigorous or species were rare. This sampling at different localities and formations allows a reliable approximation of the regional assemblage, as well as an additional level of analysis in the comparison of the relevance of the morphological variables included.

Principal Components Analysis (PCA). The general PCA reveals that the first three components account for 85.2 % of the total variation, with 63.9 % for CP1, 11.1 % for CP2 and 10.1 % for CP3 (Table 3). This same table shows quantitatively the values of the loads contributed by variables to each component; the most important variables for CP1 were ZPW, AW, and MFW (all with a positive load); for CP2 were IFL, ZPW (negative load) and MFW; and for CP3 were IFL, OL and ML (all with a positive load).

A scatter plot shows 75.1 % of this variation (Figure 3), which, together with the characterization of the principal components CP1 and CP2 along with the contribution of the different variables (Table 3), corresponds to the analysis of the regional pattern of the Andean rodent assemblage throughout the study area, providing a reference point for analyzing individual assemblages.

The arrangement of clusters of species (Figure 3) allow defining some morphometric groups based on their limited or null overlap in the space defined by components 1 and 2. These would correspond to: (A) small and delicate, located in quadrant III (*M. minutus*, *N. tenuipes*, and *R. mexicanus*); (B) small, in quadrant II (*A. affinis*, *R. latimanus*, *T. baeops*, and *T. cinnameus*); (C) medium-sized, in quadrant III (*C. instans*, *H. alfaroi*, *H. fuscatus*, *H. intectus*, and *M. caliginosus*); (D) large and delicate, quadrants I and II (*T. cinereiventer* and *T. contradictus*); and (E) large, in quadrants I (*T. nicefori* and *T. popayanus*) and IV (*N. childi* and *N. pectoralis*). To help differentiate these patterns, Figure 4 shows some skulls of representative species within each morphotype.

On the other hand, to analyze the representativeness of the observed patterns (morphogroups), analyses were performed with the data from individual localities that showed

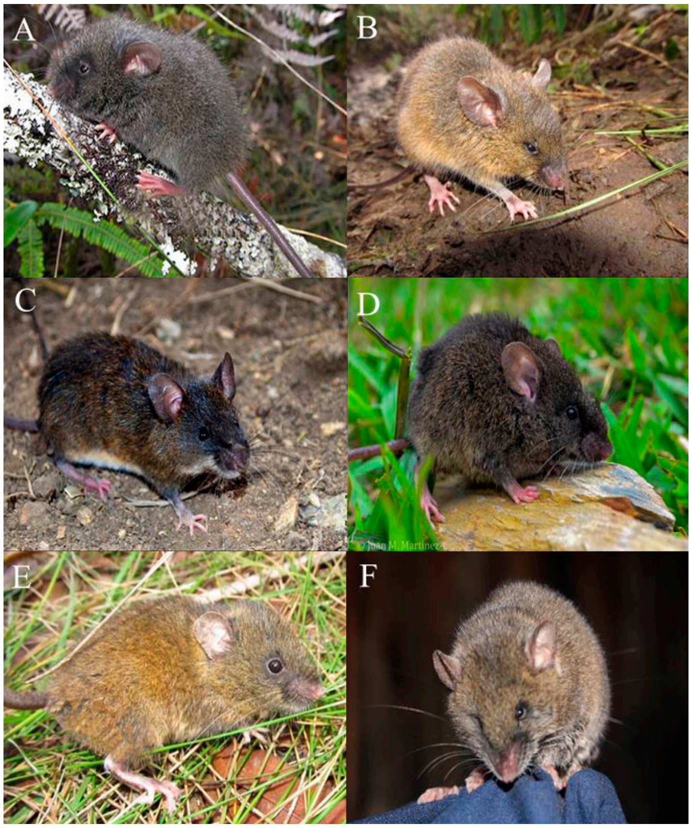

Figure 2. Some of the species recorded in the sampling of Andean rodents. Top row, *Chilomys instans* (A), *Nephelomys childi* (B); middle row, *N. pectoralis* (C), *Handleyomys fuscatus* (D); bottom row, *Thomasomys cinnameus* (E), and *T. cinereiventer* (F).

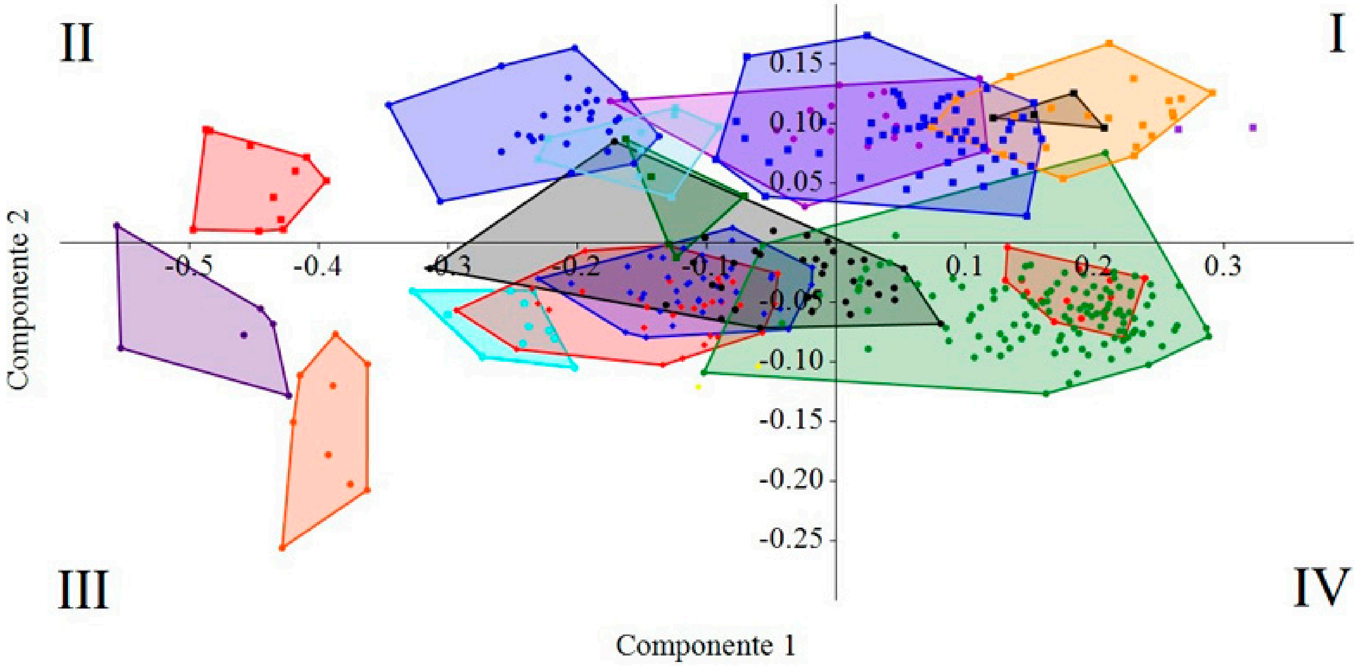

Figure 3. Scatterplot of species in the hyperdimensional space represented by CP1 and CP2 for the total data. Color polygons identify the clustering patterns of species; symbols and colors correspond to: *A. affinis* = blue dot, *C. instans* = light blue dot, *H. alfaroi* = yellow diamond, *H. fuscatus* = red diamond, *H. intectus* = blue diamond, *M. caliginosus* = black dot, *M. minutus* = índigo dot, *N. tenuipes* = orange dot, *N. childi* = red dot, *N. pectoralis* = green dot, *R. mexicanus* = red square, *R. latimanus* = dark purple dot, *T. baeops* = green square, *T. cinereiventer* = black square, *T. cinnameus* = light blue square, *T. contradictus* = blue square, *T. nicefori* = dark orange square, *T. popayanus* = purple-blue square.

the higher richness in terms of species and number of individuals. These were: Belmira (8 spp., 59 specimens), La Mesenia (7 spp., 40 specimens), Medellín (7 spp., 39 specimens), Sonsón (7 spp., 33 specimens), and Manizales (7 spp., 32 specimens).

Belmira. This locality, in the Central Cordillera (6.7072° N, -75.6888° W) and with elevations between 2,900 and 3,050 m, included a total of eight species that represented five of the morphogroups defined above: (A) *M. minutus*, *R. mexicanus*, (B) *A. affinis*, *T. baeops*, *T. cinnameus*, (D) *T. contradictus*, (E-I) *T. nicefori*, and (E-IV) *N. pectoralis*. The PCA reveals that the first three components account for 94.2 % of the variation; this value is partitioned into 86.4 % for CP1, 4.8 % for CP2, and 3.0 % for CP3. Figure 5a presents the morphospace determined by the first two components.

La Mesenia. Located in the Central Cordillera (5.5254° N, -75.9294° W) and with elevations around 2,350 m; seven species were recorded, representing five of the morphogroups defined above: (B) *A. affinis*, *R. latimanus*, (C) *H. fuscatus*, *M. caliginosus*, (D) *T. cinereiventer*, (E-I) *T. popayanus*, and (E-IV) *N. pectoralis*. In the PCA for this locality, the first three components account for 91.8 % of the variation: 82.0 % for CP1, 6.2 % for CP2, and 3.6 % for CP3. The scatter plot determined by the first two components is shown in Figure 5b.

Medellin. Located in the Central Cordillera (6.2082° N, -75.6480° W) with elevations above 2,300 m; seven species were recorded, representing all the morphogroups previously defined: (A) *M. minutus*, (B) *A. affinis*, (C) *H. intectus*, *M. caliginosus*, (D) *T. contradictus*, (E-I) *T. nicefori*, and (E-IV) *N. pectoralis*. The PCA reveals that the first three components account for 94.4 % of the total variation: 84.6 % for CP1, 6.9 % for CP2, and 2.9 % for CP3.

Sonsón. Located in the Central Cordillera (5.7182° N, -75.2469° W) and with elevations above 2,050 m; seven species were recorded, representing all the morphogroups defined above: (A) *N. tenuipes*, (B) *R. latimanus*, *T. cinnameus*, (C) *C. instans*, (D) *T. contradictus*, (E-I) *T. nicefori*, and (E-IV) *N. childi*. This PCA reveals that the first three components account for 95.6 % of the variation: 82.9 % for CP1, 9.1 % for CP2, and 3.5 % for CP3.

Manizales. Located in the Central Cordillera (5.0838° N, -75.4230° W) and with elevations of 2,550 m; seven species were recorded, representing all the morphogroups defined above: (A) *R. mexicanus*, (B) *A. affinis*, *T. baeops*, (C) *C. instans*, (D) *T. contradictus*, (E-I) *T. nicefori*, and (E-IV) *N. pectoralis*. The PCA for this locality indicates that the first three com-

Table 2. Geographical origin of specimens and number of species (# SPP) and individuals in each locality. The asterisk indicates the localities selected for the individual analysis.

Department	Regional Unit	# SPP	# Specimens
Antioquia	Aburrá Norte	7	30
Antioquia	Aburrá Sur	4	36
Antioquia	Amalfi	5	41
Antioquia	Anorí	4	18
Antioquia	Belmira*	8	59
Tolima	Cajamarca	4	9
Antioquia	Ebéjico	3	9
Antioquia	Guanacas	4	11
Antioquia	Jardín-Támesis	6	35
Antioquia	La Mesenia*	7	40
Caldas	Manizales*	7	32
Antioquia	Medellín*	7	39
Antioquia	Sonsón*	7	33
Antioquia	Yarumal	6	32
		Total	**424**

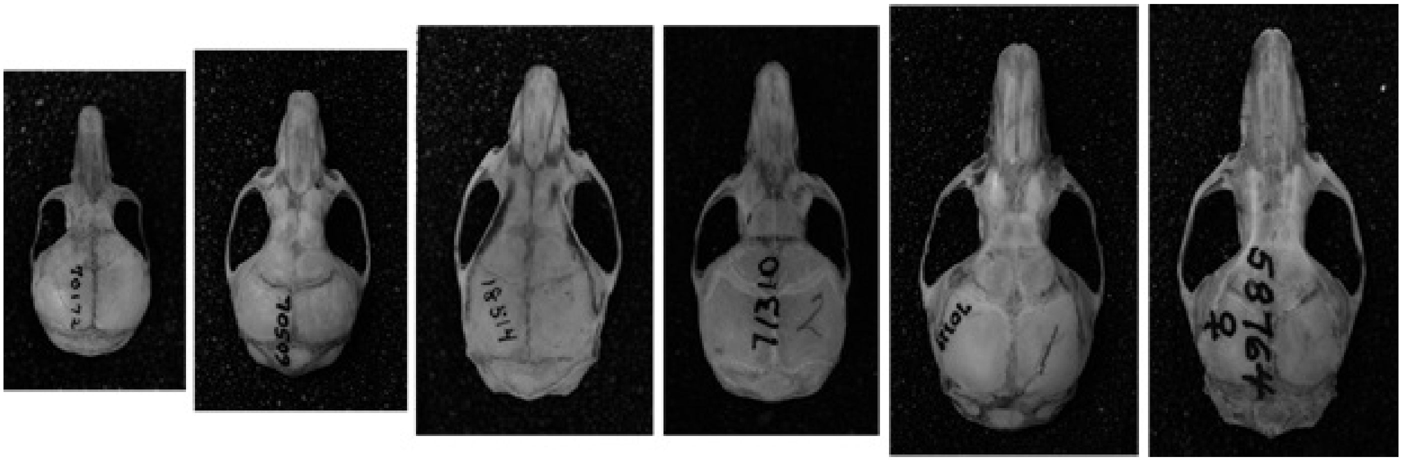

Figure 4. Representative skulls of the morphotypes identified in PCA. From left to right: *Reithrodontomys mexicanus* (group A), *Handleyomys alfaroi* (group B), *Melanomys caliginosus* (group C), *Thomasomys cinereiventer* (group D), *Nephelomys childi* (group E-IV), and *Thomasomys nicefori* (group E-I). All skulls are shown at the same scale; the bar at the far right is equivalent to 20 mm.

ponents account for 92.7 % of the variation: 83.3 % for CP1, 5.3 % for CP2, and 4.1 % for CP3.

Discussion

In general, among the local assemblages of high-Andean rodents of Antioquia, a species arrangement model can be seen where there are differences in the size and shape of the species (skull morphometry), a pattern that can be corroborated in the scatter plots (Figures 3, and 5), as well as in the analysis of loads (factorial coefficients) of the relevant variables for each component. With regard to the first aspect, cricetids are characterized by morphotypes associated with different trophic niches (Pizzimenti and De Salle 1980), many of which are presented in this analysis and are distributed across the space defined by the first two main components. This separation was further evidenced when local communities were analyzed, with the few species (seven to eight) being segregated in a differential way between the various assemblages (Figure 5).

Table 3. Table of the factorial coefficients associated with the first three components of the analysis of total assemblages. Autovalues and the percentage of variance represented by each component are shown. The acronyms used are indicated in the Methodology section.

	PC 1	PC 2	PC 3
Autovalue	0.03505	0.00610	0.00556
% variance	63.91500	11.14000	10.13900
CIL	0.33294	-0.00060	0.09756
AC	0.32851	0.01370	0.09588
MW	0.19170	0.14343	0.04610
MIC	0.13317	0.20142	0.02826
RL	0.37792	0.12214	-0.23732
NL	0.01302	-0.09495	0.04311
AW	0.03362	-0.17398	0.10504
OL	0.05159	-0.14544	0.38551
DL	0.03166	-0.07770	0.22653
ML	0.04031	0.02358	0.35136
IFL	-0.00186	0.61348	0.61249
PBL	0.04160	-0.16231	0.27053
AW	0.40041	0.18061	-0.07788
MFW	0.39964	0.32658	-0.29473
ZPW	0.50553	-0.56102	0.21095

When the presence of these six morphogroups was analyzed, as defined by the PCA at a regional scale, it is evident that there is zero to minimal overlap in the morphometric space between species at the local scale, although this is also a consequence of a lower representativeness in the number of species (with a maximum of eight in Belmira and La Mesenia). However, it is remarkable that all morphogroups occur in the localities with fewer species (seven). It should be noted that the majority of these morphogroups do not correspond to taxonomic divisions, and that these divisions do not behave as a single unit with regard to morphology.

However, in the scatter plot of the regional assemblage this pattern should not be interpreted in a manner similar to the local one, since the inclusion of the whole sample in a single analysis results in the overlap between species within the same morphogroup (*e. g., N. childi* and *N. pectoralis*; Figure 3). Since some authors (Pianka 1973, Gotelli and Ellison 2002; Adams 2007) point to that a wide competition would not be favored in natural assemblages, this co-occurrence would indicate that other factors are acting at the level of that assemblage. However, as recorded in our sampling and other studies (Percequillo 2003), these two species are not sympatric. In contrast, sympatry may occur in some cases, such as in Belmira with *T. baeops* and *T. cinnameus* (Figure 5a), which would indicate that additional factors would be offsetting the potential competition (for example, character displacement).

Among the variables analyzed, there are five (ZPW, MFW, IFL, ML and RW; Table 4) that account for most of the variation in the overall analysis and the individual analyses, while at the same time, four others (CIL, ZW, MW and PBL) did not contribute significantly in any PCA of these localities (therefore, these are not shown). In this way, the arrangement of morphometric variables would allow inferring an ecological separation of species, as evidenced in the morphogroups identified. Although these variables are not directly related to size as such, these could play a key role in the segregation of resources between species from an anatomical point of view (Landry 1970), determining muscular

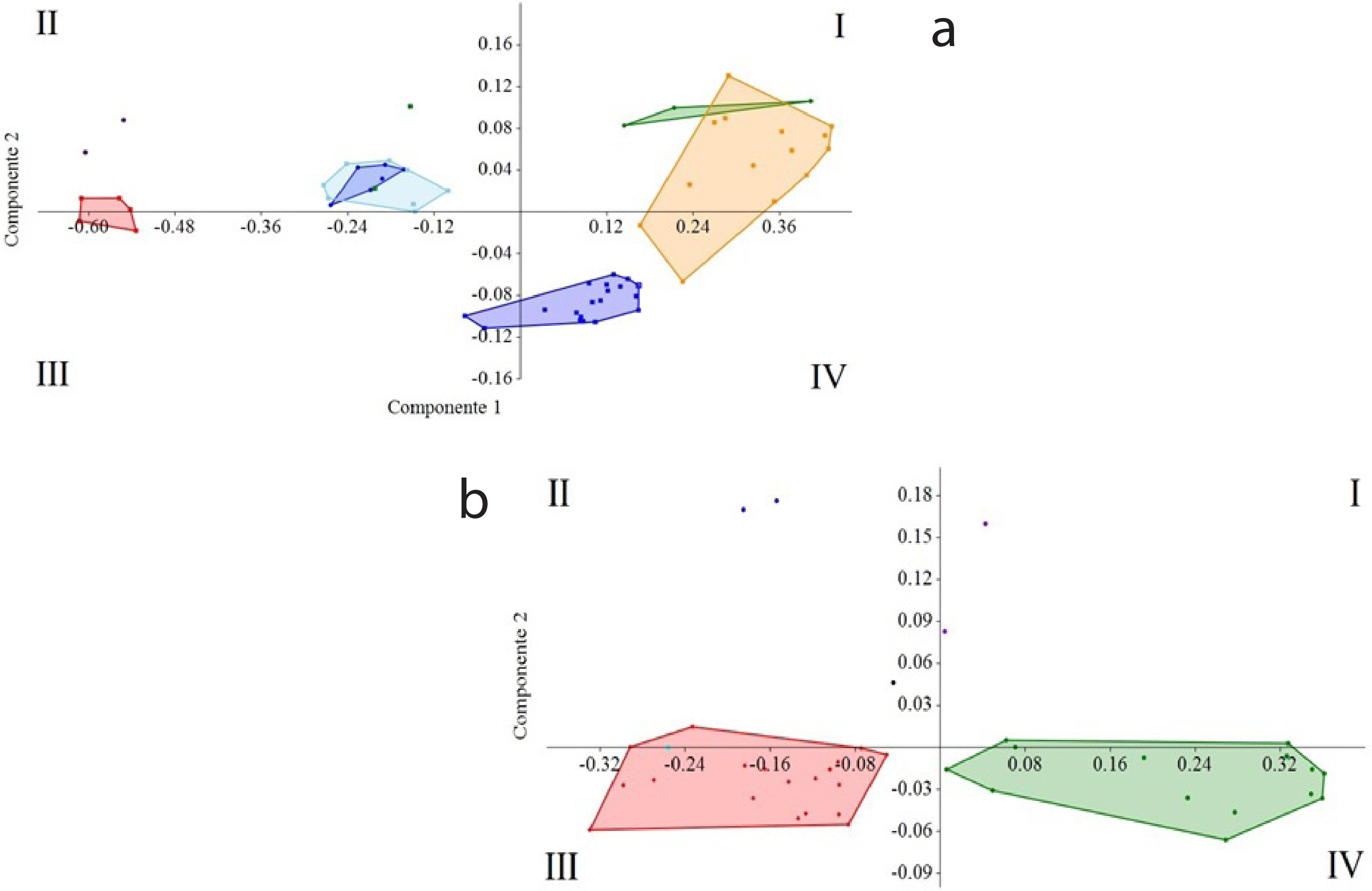

Figure 5. Scatterplot of the species recorded in some local assemblages shown in the hyperdimensional space represented by CP1 and CP2. Symbols and colors are as in Figure 3. (a) Belmira, Central Cordillera, (b) La Mesenia, Western Cordillera.

insertions (ZPW) or passage of food to the digestive tube (MFW). In a study of the rodent *Peromyscus zarhynchus*, Lorenzo *et al.* (2006) suggest that morphometric differences between geographical populations seem to be influenced by the variation in the type of food available in these areas. Gould (1966) mentions that evolutionary allometry represents real temporal changes of ratios within a genetic continuum; due to the relationship between these shape, ecological segregation can function as a mechanism favoring differences between species of the same genus, even before promoting geographical isolation. Further studies with a greater emphasis on ecomorphological aspects could unveil the role of these variables in the segregation between species. Likewise, other aspects should also be

Table 4. Summary of the variables with the three largest loads in the first three principal components (CP1, CP2, CP3) of the five individual analysis. The acronyms used are indicated in the Methodology section.

	Belmira			**La Mesenia**			**Medellín**			**Sonsón**			**Manizales**		
	CP1	CP2	CP3	CP1	CP2	CP3	CP1	CP2	CP3	CP1	CP2	CP3	CP1	CP2	CP3
MIC						-0.209		0.187			0.414				
RL													0.338		
NL						0.309							0.345		
AW			-0.292		-0.149				0.536			-0.248		-0.397	
OL				0.310											
DL							0.302								0.234
ML	0.339			0.300						0.334				0.618	
IFL		0.380	0.743		0.796			0.727	-0.472			0.696		0.6189	
AW	0.324														
MFW		-0.472				0.802	0.311		0.486	0.322	0.360	-0.521	0.451		-0.250
ZPW	0.322	0.465	-0.516	0.390	-0.505		0.346	-0.612		0.343	-0.689				0.786

considered, such as diet at the local level (see Pizzimenti and De Salle 1980; Giménez and Giannini 2011), selection of specific microhabitats (Vitt *et al.* 2000), and evolutionary relationships between species, to understand the dynamics and organization of these assemblages.

Although the procedure of combining localities that are geographically close allowed to obtain some interesting approximations, in the long term it is recommended to include only localities with sufficiently comprehensive sampling to elucidate the complex of rodents inhabiting these Andean forests. Methodologically, combining undersampled localities can lead to further error in the analysis, or may confound the actual assemblage patterns. For example, localities such as La Mesenia (Western Cordillera) or Belmira (Central Cordillera) have comparable numbers of species and individuals, revealing patterns not only regarding presence but also abundance, which would be more informative to raise additional questions to this study.

Localities sampled evenly can also contribute to the knowledge of geographic patterns for species, which in many cases show discontinuities not attributable to any geographical or ecological barrier. For instance, we found that *N. pectoralis* was collected in four of the five individual localities, but its distribution is interrupted by its sister species *N. childi*, which was recorded only in Sonsón. In other cases, there are species that do not occur in both cordilleras, outlining a biogeographical exclusion pattern (Voss *et al.* 2002; Pacheco 2003; Percequillo 2003). Such is the case of some species of *Thomasomys*; for example, *T. popayanus* and *T. cinereiventer* in the Western Cordillera; and *T. baeops*, *T. contradictus, T. cinnameus,* and *T. nicefori* in the Central Cordillera. However, the lack of sampling rigor precludes the detection of a real pattern, since there are rare species that can only be captured in specific microhabitats or after intense sampling (Sánchez-Giraldo and Díaz-Nieto 2015).

In addition, there are still information gaps on the ecology of high-Andean rodents in Colombia, especially regarding diet-related topics (Montenegro-Díaz *et al.* 1991; Lopez-Arevalo *et al.* 1993; Solari 2007), which considerably reduces the resolution power of this approximation. Likewise, we must take into account the restricted distribution of some of the species included in the analyses. For example, the genera *Handleyomys, Nephelomys* and *Thomasomys* show pairs of similar species with an allopatric distribution (Voss *et al.* 2002; Pacheco 2003; Percequillo 2003). However, this gap is likely influenced also by their taxonomic closeness, making it difficult to find species with very similar morphology in the same locality (Bowers and Brown 1982, Gotelli and Ellison 2002).

These fundamental factors influence assemblage rules, so it was not possible to demonstrate a structure that is maintained from the regional scale to that of local assemblages. Besides, the geographical isolation of the various assemblages may result in different combinations of species and particular relationships within the morphometric space. In this sense, although ecomorphological analyses are an effective tool for understanding the assemblages and organization in a community (Pizzimenti and De Salle 1980; Ricklefs and Travis 1980; Arita 1997; Moreno *et al.* 2006; Giménez and Giannini 2011), these were not conclusive in this particular case. However, this first approximation shows the usefulness of regional studies to understand patterns of species diversity and replacement, which should be supplemented by analyses of ecological aspects such as diet composition, microhabitat, foraging strategies, and periods of activity (Bruseo and Barry 1995; Arita 1997; Vitt *et al.* 2000) to interpret the coexistence of various species in a local assemblage.

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Literature cited

Adams, D. C. 2007. Organization of *Pletodon* salamander communities: guild-based community assembly. Ecology 88:1292-1299.

Arita, H. T. 1997. Species composition and morphological structure of the bat fauna of Yucatan, Mexico. Journal of Animal Ecology 66:83-97.

Bowers, M. A., and J. H. Brown. 1982. Body size and coexistence in desert rodents: chance or community structure? Ecology 63:391-400.

Bruseo, J. A., and R. E. Barry. 1995. Temporal activity of syntopic *Peromyscus* in the Central Appalachians. Journal of Mammalogy 76:78-82.

Connor, E. F., and D. Simberloff. 1979. The Assembly of Species Communities: Chance or Competition? Ecology 60:1132-1140.

Crisci, J. V., and M. F. López-A. 1983. Introducción a la teoría y práctica de la taxonomía numérica. Secretaría General de la Organización de Estados Americanos (OEA). Washington, U S. A.

Diamond, J. M. 1975. Assembly of species communities. Pp. 342-444, in Ecology and evolution of communities (Cody, M., and J. M. Diamond, eds.). Harvard University Press. Cambridge, U S. A.

Fauth, J. E., J. Bernardo, M. Camara, W. J. Resetarits, J. Van Buskirk, and S. A. McCollum. 1996. Simplifying the jargon of community ecology: a conceptual approach. The American Naturalist 147:282-286.

Findley, J. S. 1975. The structure of bat communities. The American Naturalist 110:129-139.

Freeman, P. W. 1998. Form, function, and evolution in skulls and teeth of bats. Pp. 140-156, in Bat Biology and Conservation (Kunz, T. H. and P. A. Racey, eds.). Smithsonian Institution Press. Washington, USA.

Freeman, P. W. 1981. A multivariate study of the family Molossidae (Mammalia, Chiroptera): morphology, ecology, evolution. Fieldiana, Zoology, new series 7:1-173.

Giménez, A., and N. Giannini. 2011. Morphological and geographic segregation among species of lasiurine bats (Chiroptera: Vespertilionidae) from the South American southern cone. Mammalia 75:173-179.

Gómez-Valencia, B. 2006. Estructura de la comunidad de pequeños mamíferos en un gradiente altitudinal, Reserva Río Blanco, Manizales, Caldas, Colombia [Trabajo de pregrado]. Universidad Nacional de Colombia. Bogotá, Colombia.

Gotelli, N. J., and A. M. Ellison. 2002. Assembly rules for New England ant communities. Oikos 99:591-599.

Gould, S. J. 1966. Allometry and size in ontogeny and phylogeny. Biological Reviews 41:587-640.

Hammer, Ø., D. A. Harper, and P. D. Ryan. 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4:9.

James, F. C., and C. E. McCulloch. 1990. Multivariate Analysis in Ecology and Systematics: Panacea or Pandora's Box? Annual Review of Ecology and Systematics 21:129-166.

Jackson, D. A. 1993. Stopping rules in principal components analysis: a comparison of heuristical and statistical approach. Ecology 74:2204-2214.

Landry, S. 1970. The Rodentia as omnivores. The Quarterly Review of Biology 45:351-372.

López-Arévalo, H., O. Montenegro-Díaz, and A. Cadena. 1993. Ecología de los pequeños mamíferos de la Reserva Biológica Carpanta, en la Cordillera Oriental colombiana. Studies on Neotropical Fauna and Environment 28:93-210.

Lorenzo, C., L. Cuautle, E. Espinoza, and M. García. 2006. Intraspecific variation in *Peromyscus zarhynchus* (Rodentia: Muridae) from Chiapas, Mexico. Journal of Mammalogy 87:683-689.

Montenegro-Díaz, O., H. López-Arévalo, and A. Cadena. 1991. Aspectos ecológicos del roedor arborícola *Rhipidomys latimanus* Tomes, 1860 (Rodentia, Cricetidae) en el oriente de Cundinamarca, Colombia. Caldasia 16:565-572.

Moreno, C. E., H. T. Arita, and L. Solis. 2006. Morphological assembly mechanisms in Neotropical bat assemblages and ensembles within a landscape. Oecologia 149:133–140.

Muñoz-Saba, Y., J. O. Rangel, and A. Cadena. 2000. Mamíferos. Pp. 599-611, in Colombia: Diversidad Biótica III. La Región de vida Paramuna (Rangel, J.O., ed.). Universidad Nacional de Colombia. Bogotá, Colombia.

Norman, G. R., and D. L. Streiner. 1996. Bioestadística. Harcourt Brace, Edición en español. Madrid, España.

Otarola-Ardila, A. 2003. Mamíferos de los bosques de roble. Acta Biológica Colombiana 8:57-71.

Pacheco, V. 2003. Phylogenetic Analyses of the Thomasomyini (Muroidea Sigmodontinae) based on morphological data [Doctoral dissertation]. The City University of New York. New York, USA.

Patterson, B. D. 1999**.** Contingency and determinism in mammalian biogeography: the role of history. Journal of Mammalogy 80:345-360.

Patton, J. L., M. N. F. da Silva, and J. R. Malcolm. 2000. Mammals of the Rio Juruá and the evolutionary and ecological diversification of Amazonia. Bulletin of the American Museum of Natural History 244:1-306.

Patton, J. L., U. F. Pardiñas, and G. D'Elía. 2015. Mammals of South America, Volume 2: Rodents. University of Chicago Press. Chicago, U S. A.

Percequillo, A. R. 2003. Sistemática de *Oryzomys* Baird, 1858: definição dos grupos de espécies e revisão taxonômica do grupo *albigularis* (Rodentia, Sigmodontinae) [Doctoral dissertation]. Universidade de São Paulo. São Paulo, Brasil.

Peres-Neto, P. R., D. A. Jackson, and K. M. Somers. 2003. Giving meaningful interpretation to ordination axes: assessing loading significance in principal component analysis. Ecology 84:2347–2363.

Pianka, E. R. 1973. The structure of lizard communities. Annual Review of Ecology and Systematics 4:53-74.

Pizzimenti, J. J., and R. de Salle. 1980. Dietary and morphometric variation in some Peruvian rodent communities: the effect of feeding strategy on evolution. Biological Journal of the Linnean Society 13:263-285.

Ricklefs, R. E., and J. Travis. 1980. A morphological approach to the study of avian community organization. The Auk 97:321-338.

Sánchez, F., P. Sánchez-Palomino, and A. Cadena. 2004. Inventario de mamíferos en un bosque de los Andes centrales de Colombia. Caldasia 26: 291-309.

Sánchez-Giraldo, C., and J. F. Díaz-Nieto. 2015. Dynamics of species composition of small nonvolant mammals from the northern Cordillera Central of Colombia. Mammalia 79:385-397.

Solari, S. 2007. Trophic relationships in a highland rodent assemblage of Manu National Park, Cusco, Peru. Pp. 225-240, in The Quintessential Naturalist: honoring the Life and Legacy of Oliver P. Pearson (Kelt, D.A., E. Lessa, J. Salazar-Bravo, and J. L. Patton, eds.). University of California Publications in Zoology, 134. University of California Press. Los Angeles, U S. A.

Soriano, P., A. Díaz de Pascual, J. Ochoa, and M. Aguilera. 1999. Las comunidades de roedores de los Andes Venezolanos. Acta Zoológica Mexicana, volumen especial 1998:211-226

Viancha-Sánchez, A., J. Cepeda-Gómez, E. Muñoz-López, A. Hernández-Ochoa, and L. Rosero-Lasprilla. 2012. Mamíferos pequeños no voladores del Parque Natural Municipal Ranchería, Paipa, Boyacá, Colombia. Revista Biodiversidad Neotropical 2:37-44.

Vitt, L. J., S. S. Sartorius, T. S. C. Avila-Pires, M. C. Esposito, and D. B. Miles. 2000. Niche segregation among sympatric Amazonian teiid lizards. Oecologia 122:410-420.

Voss, R. S. 2003. A new species of *Thomasomys* (Rodentia: Muridae) from Eastern Ecuador with remarks on mammalian diversity and biogeography in the Cordillera Oriental. American Museum Novitates 3421:1-47.

Voss, R. S., M. Gómez-Laverde, and V. Pacheco. 2002. A new genus for *Aepeomys fuscus* Allen, 1912, and *Oryzomys insectus* Thomas, 1921: enigmatic Murid rodents from the Andean cloud forest. American Museum Novitates 3373:1-42.

Voss, R. S., D. P. Lunde D. P., and N. B. Simmons. 2001. The mammals of Paracou, French Guiana: a Neotropical lowland rainforest fauna Part 2. Nonvolant species. Bulletin of the American Museum of Natural History 263:1-236.

Weksler, M. 2006. Phylogenetic relationships of Oryzomyine rodents (Muroidea: Sigmodontinae): separate and combined analyses of morphological and molecular data. Bulletin of the American Museum of Natural History 296:1-149.

Weksler, M., and A. R. Percequillo. 2011. Key to the genera of the tribe Oryzomyini (Rodentia: Cricetidae: Sigmodontinae). Mastozoología Neotropical 18:281-292.

Willig, M. R. 1986. Bat community structure in South America: a tenacious chimera. Revista Chilena de Historia Natural 52:151-168.

Willig, M. R., and M. P. Moulton. 1989. The role of stochastic and deterministic processes in structuring Neotropical bat communities. Journal of Mammalogy 70:323-329.

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First photographic evidence of the iconic big mammals of Honduras, Baird's Tapir (*Tapirus bairdii*) and Jaguar (*Panthera onca*), in La Muralla Wildlife Refuge

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In Honduras, the biggest land mammals found are the Baird's tapir and the jaguar. Both species have been documented previously for La Muralla Wildlife Refuge, Olancho, Honduras, but there has never been photographic evidence of their presence. In the present, we show the first photographic evidence for both species captured using camera-traps during a one month period. With this evidence new conservation efforts can be planned taking in consideration the recent presence of both iconic species in the refuge and the country as well as an important connectivity spot for the species populations.

En Honduras, los mamíferos terrestres más grandes son el tapir de Baird y el jaguar. Ambas especies han sido documentadas previamente para El Refugio de Vida Silvestre La Muralla, Olancho, Honduras, pero no había sido presentada una evidencia fotográfica de su presencia. En el presente, mostramos los primeros registros fotográficos para ambas especies capturadas mediante trampas cámara en el periodo de un mes de trabajo. Con estas nuevas evidencias se pueden desarrollar esfuerzos de conservación que tomen en consideración la presencia reciente de ambas especies icónicas para el refugio y el país en general, así como un punto de conectividad importante para las poblaciones de ambas especies.

Key words: camera traps; connectivity spot; Honduras.

Introduction

Possibly the two most iconic species of land mammals that anyone can find in Honduras and Central America are the Baird's tapir (*Tapirus bairdii*) and the jaguar (*Panthera onca*). Both species were historically distributed in most of Honduran territory, but due to habitat loss, forest fragmentation, and hunting pressures they can only be found in some forest remnants in the western parts (La Mosktia and Patuca region) and the north coast, Nombre de Dios and Merendón mountain ranges (ICF 2011a; ICF 2011b) of Honduras.

The distribution of both species in the country's central part lacks of evidence of their presence. Occurrence of the tapir was reported for the Agalta and Carbon mountain ranges in the departments of Olancho and Colon (Flesher 1999; Estrada 2004), and it has been widely found in the Moskitia Biosphere region according to studies by different authors (Estrada 2006; Castañeda 2009; Hernandez and Portillo 2008; Townsend 2002b). It has also been reported from Cusuco National Park, in the east mountain ranges of Merendón (Operation Wallacea 2006). The distribution of the jaguar is similar, it has been reported several times for the Moskitia Biosphere (Cruz 2001; Castañeda 2009; Polisar *et al.* 2009; Portillo *et al.* 2008). For the north coast there have been several reports for Pico Bonito National Park and Jeannette Kawas National Park (Castañeda *et al.* 2011a; 2011b).

There have been studies with camera traps conducted inside La Muralla Wildlife Refuge with no photographic results of either species (Moreno 2012; Portillo and Elvir 2013a; Portillo and Elvir 2013b). Portillo and Elvir (2013a) conducted a study of cats (Felidae) in protected areas in Honduras, in which one of the study sites was La Muralla Wildlife Refuge. In that study they found three species of cats, puma (*Puma concolor*), ocelot (*Leopardus pardalis*), and margay (*L. wiedii*), but they do not mention any evidence about the presence of jaguar. Moreno (2012) reports the presence of tapir in the refuge based on a footprint found in one of the trials, but failed to provide a photographic proof of the species. In the same document, the author reports puma (*Puma concolor*) as the biggest cat in the park, but did not find any evidence whatsoever of jaguar in the refuge. The Centro de Estudios Ambientales de Honduras (CEAH; 2010) elaborated the management plan for the refuge, but were unsure about the presence of jaguar. They also report the presence of tapir, and provide the picture of a tapir's skull that is shown in the visitor center, but fail to provide further information like the exact place and date where it was found. Portillo and Elvir (2013b) report the presence of tapir in La Muralla Wildlife Refuge based on a study using camera traps; nevertheless, Portillo (2016, pers. comm.) states that the evidence comes from Moreno's (2012) footprint previous report, meaning that there is still no camera-trap evidence for the species. Here we present the first photographic evidence for tapir and jaguar from La Muralla Wildlife Refuge, Olancho, Honduras.

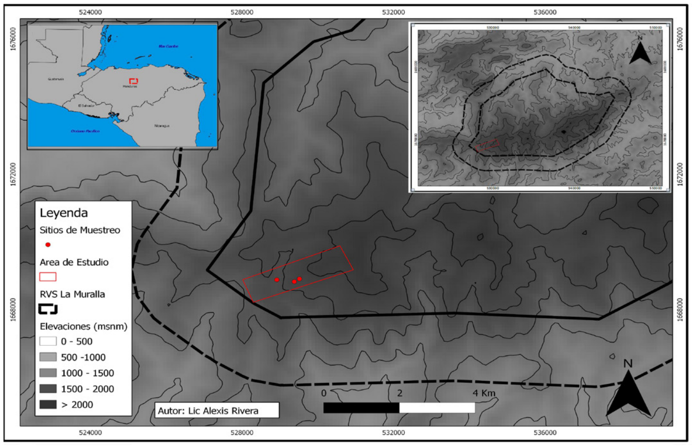

Figure 1. Location of Camera Traps in La Muralla Wildlife Refuge.

Materials and Methods

La Muralla Wildlife Refuge is a protected area in the Olancho Department in the northeastern region of Honduras. It has an extension of 26,903 hectares and forms part of the Agalta Mountain range. The mayor part of the Refuge is covered by broad leaf forest, having a mean temperature between 12 to 18 °C. It has fragmented landscapes used mainly for agricultural activities. The forest plot where the cameras where set corresponds to a primary tropical cloud forest with a mature vegetation and trees with over 35 meters height, with dominant species like *Brosimum alicatrum* (Masica), *Calatola costarisensis* (Nogal), *Nectandra* sp. (Rosita), and *Persea* sp., and a forest floor covered mostly by grass.

For a brief survey conducted in La Muralla Wildlife Refuge we set three camera traps (Browning Strike Force BTC5-Browning Trial Cameras, U. S. A) along the "Monte Escondido" trial on the 8th of August 2015 (Figure 1). The camera traps where then recollected the 13th of September which sums a total of 36 nights/camera. All the cameras where set next to the trial and programed for pictures only.

Results

A total of 164 pictures where obtained from the three cameras, 30 of those were of one tapir in a single event (Captured on T2, 25 August 2015, 6:06 pm; 15.094903°, -86.726429°), this represents the 18.3 % of the total. Five pictures were of one jaguar in a single event (Captured on T3, 9 September 2015, 3:33 am; 15.095643°, -86.725163°), which represents the 3.05 %. Based on these images we could determine that the specimen of tapir is an adult male and the jaguar is an adult of unknown sex (Figure 2).

Discussion

The presence of these two species in La Muralla Wildlife Refuge, as well as other interesting species such as ocelot (*Leopardus pardalis*), margay (*L. wiedii*), and agoutis (*Cuniculus paca*), is an indicative of the good state of conservation of the refuge. It is known that tapirs inhabit habitats with low to none human intervention because they need areas that will serve as foraging places, with enough food availability and big spaces providing resources for their wellbeing. The scenario for the jaguar is basically the same, with the difference that it has been proved that they can coexist closer to humans, evidence of this is the cattle conflict there has been going on for years all over the Americas. Nevertheless, the habitat in Honduras has been so fragmented and areas deforested to the point that both species are now limited to the high and isolated parts of protected areas where human intervention is less noticeable, or in the wide savannas of the Moskitia region.

The Muralla Wildlife Refuge is a remarkable spot for both the tapir and jaguar connectivity because of the geographic position it has in the country. This is why this report is important in order to consider La Muralla as a connectivity area among populations throughout the different protected areas in the country. Even though Flesher (1999) and Estrada (2004) confirmed the presence of tapirs for the Agalta range, this report, along with Moreno's footprint (2012), can be considered the most relevant record for the species at the Refuge. Considering the Initiative for the Jaguar Corridor in Honduras (Panthera 2014a) and the actual present range reported by Panthera (2014b), it is clear the importance of jaguar's presence at the refuge which is serving as a connectivity spot along the country. La Muralla Wildlife Refuge must be considered a key place for conservation and management plans to protect this two endangered species.

Figure 2. A) Adult male specimen of Baird's Tapir (*Tapirus bairdii*), Monte Escondido Trial, La Muralla. Captured in T2 (15.094903°, -86.726429°). B) Adult specimen of Jaguar (*Panthera onca*), Monte Escondido Trial, La Muralla. Captured in T3 (15.095643°, -86.725163°).

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Literature cited

Castañeda, F. 2009. Datos preliminares sobre la distribución del jaguar (*Panthera onca*), el estado de sus especie presa, y el conflicto felinos-ganadería en la Moskitia Hondureña. Wildlife Conservation Society, Tegucigalpa, Honduras.

Castañeda, F., S. Pereira, and M. Solís. 2011a. In the middle of the corridor: status of *Panthera onca* at Pico Bonito National Park, Honduras. Revista Mesoamericana 15:73.

Castañeda, F., L. Herrera, S. Pereira, and D. Sierra. 2011b. Estado del jaguar (*Panthera onca*) en el Parque Nacional Jeannette Kawas, Honduras. Panthera, Prolansate, Instituto Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre. Tegucigalpa, Honduras.

Centro de Estudios Ambientales de Honduras. 2010. Plan de Manejo Refugio de Vida Silvestre La Muralla 2011-2015. Instituto Nacional de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre- Departamento de Áreas Protegidas (DAP). Tegucigalpa, Honduras.

Cruz, G. 2001. Preliminary results on cat-cattle conflicts in Brus Laguna, La Moskitia. WCS. In: Instituto Nacional Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre. 2011b. Plan Nacional para la Conservación del Jaguar (*Panthera onca*); Promoviendo la convivencia Comunidad-Jaguar. Departamento de Vida Silvestre/ Instituto Nacional de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre- Proyecto Ecosistemas-Fundación Panthera. Tegucigalpa, Honduras.

Estrada, N. 2004. Notes on the relative abundance and hunting of baird's tapir in the Rus-Rus region of la moskitia, Honduras: a proposed biological reserve. Tapir Conservation 13:28-29

Estrada, N. 2006. Ecología del Danto (*Tapirus bairdii*) en el Parque Nacional Sierra de Agalta, Olancho, Honduras. Proyecto USAID/MIRA. Tegucigalpa, Honduras.

Flesher, K. 1999. Preliminary notes on the conservation status of Baird's tapir T*apirus bairdii* in north-eastern Honduras. Oryx 33:294-300

Hernández, J., and H. Portillo. 2008. Abundancia relativa de tapir en Rus Rus, Honduras, 3p, in ICF. 2011a. Plan Nacional para la Conservación del Danto (*Tapirus bairdii*), N. Estrada, S. Bonilla y J. Mora. Departamento de Vida Silvestre/ Instituto Nacional de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre-Proyecto Ecosistemas-Grupo de Especialistas de Tapires SSC-UICN. Tegucigalpa, Honduras.

Instituto Nacional de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre. 2011a. Plan Nacional para la Conservación del Danto (*Tapirus bairdii*). Departamento de Vida Silvestre/ Instituto Nacional de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre-Proyecto Ecosistemas-Grupo de Especialistas de Tapires SSC-UICN. Tegucigalpa, Honduras.

Instituto Nacional de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre. 2011b. Plan Nacional para la Conservación del Jaguar (*Panthera onca*); Promoviendo la convivencia Comunidad-Jaguar. Departamento de Vida Silvestre/ Instituto Nacional de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre- Proyecto Ecosistemas-Fundación Panthera. Tegucigalpa, Honduras.

Operation Wallacea. 2006. Baird's tapir monitoring. In: Field Report: University of Nottingham/ Operation Wallacea Forest Projects, Honduras 2006. Nottingham, United Kingdom. Retrieved from: https://opwall.com/wp-content/uploads/Cusuco-Field-Report-2006.pdf

Panthera. 2014a. La Iniciativa del Corredor del Jaguar; creando un paso seguro para los Jaguares en el Presente y hacia el Futuro. Panthera. New York, U. S. A. Retrieved from: https://www.panthera.org/initiative/jaguar-corridor-initiative

Panthera. 2014b. Jaguar's Historic and Current Range. Panthera. New York, U. S. A. Retrieved from: https://www.panthera.org/cms/sites/default/files/Jaguar_Current_and_Historic_Range_Feb_2014_HSR_0.pdf

Polisar, J., J. Mora, F. Castañeda, and L. I. López. 2009. Talleres de Manejo de Fincas Ganaderas y Conservación de Jaguar (*Panthera onca*) en los Valles y Llanos de La Mosquitia Hondureña. Reporte técnico para Wildlife Conservation Society. Tegucigalpa, Honduras.

Portillo, H., T. Manzanares, T. Manzanares, Jr., S. Lacut, and R. Lacut. 2008. Estimating Jaguar Population Using Traps Camera in One Hundred Square Kilometers in Rus Rus La Mosquitia, Honduras. Wildlife Conservation Society. Tegucigalpa, Honduras.

Moreno, R. 2012. Primer Informe Inventariado de Integridad Ecológica Realizada para el Refugio de Vida Silvestre La Muralla. Fundación PANAM. La Unión, Honduras.

Portillo, H., and F. Elvir. 2013a. Distribución de Felinos Silvestres en Áreas Protegidas de Honduras. Revista Mexicana de Mastozoología. 3:26-35

Portillo, H., and F. Elvir. 2013b. Composición, Estructura y Diversidad de Mamíferos Terrestres Grandes y Medianos en 16 Áreas Protegidas en Honduras, Usando fotocapturas como Evidencia de Registro. Mesoamericana 17:15-29

Townsend, J. 2002b. Notes on the Baird's Tapir (*Tapirus bairdii*) from the southern region of Biosfera Tawahka-Asagni, Honduras. Tapir Conservation 11:16-17

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The first record of *Calomys hummelincki* (Rodentia: Sigmodontinae) from the Lavrados of northern Brazil

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The South American genus *Calomys* exhibits a disjunct distribution with most species inhabiting grasslands, savannas, and forest edges from *ca.* latitude 8° S in the highlands of Peru and the Caatinga of Brazil to *ca.* latitude 16° S in central Bolivia, and from there south into Argentine Patagonia. Only a single species (*Calomys hummelincki*) occurs in open habitats in northern South America. We report the first known specimen of *Calomys hummelincki* for Brazil. The specimen is deposited in the mammal collection of Museu de Zoologia da Universidade de São Paulo, São Paulo. It is a young adult female with two embryos collected on 13 March 1989 by C. M. Carvalho at Fazenda Salvamento, Roraima state, during a herpetofaunal survey. The specimen shares qualitative and quantitative characters with specimens from Venezuela and Curaçao, but also differs substantially in others. The record presented herein extends the known range of the species about 630 km southeastward from the nearest previous record (in Venezuela, Estado Bolívar, Sipao). This new record was obtained in a locality representative of the savannas of the Rio Branco – Rupununi region that supports a poorly known, but distinctive mammalian fauna. This entire eco-region represents a piece of the biogeographic puzzle resulting from the climate-dependent vegetation shifts that dominated the Quaternary of South America. This new record highlights the need to investigate and protect the biodiversity of the Rio Branco-Rupununi savannas.

El género Sudamericano *Calomys* presenta una distribución discontinua, con la mayoría de sus especies presentes en los pastizales, sabanas y bordes del bosque desde 8 °S latitud S en el altiplano de Perú y la Caatinga de Brasil hasta lat 16 °S en el centro de Bolivia y desde allí hacia el sur, hacia la Patagonia Argentina. En este trabajo presentamos el primer registro de *Calomys hummelincki* para Brasil, basado en un espécimen que se encuentra depositado en la colección de mamíferos del Museo de Zoología de la Universidade de São Paulo, São Paulo. Específicamente, se trata de una hembra adulta joven con dos embriones y que fue atrapada el 13 de marzo de 1989 por C. M. Carvalho en la Fazenda Salvamento, en el estado de Roraima, durante un levantamiento de herpetofauna. Este espécimen comparte caracteres métricos y cualitativos con individuos de la misma especie y de poblaciones en Venezuela y Curaçao, aunque al mismo tiempo, difiere substancialmente en otros. El registro presentado en este trabajo extiende en alrededor de 630 km SE la distribución de la especie desde el registro más cercano (Venezuela, Estado Bolívar, Sipao). El registro aquí reportado proviene del sistema de sabanas denominadas del Río Branco-Rupununi, un ecosistema que contiene una fauna de mamíferos única y poco conocida. Este ecosistema representa una pieza importante en el rompecabezas biogeográfico que resultó de los cambios de vegetación que dominaron el Cuaternario de Sudamérica. Se destaca la necesidad de estudiar y proteger la biodiversidad de las sabanas Rio Branco-Rupununi.

Key words: Cerrado enclaves; Hummelinck's vesper mouse; Neotropical savannas; range extension.

Introduction

Species of the genus *Calomys* Waterhouse, 1837 are small, mostly granivorous, rodents of the tribe Phyllotini. Despite being broadly distributed throughout open vegetation formations in South America and on islands off Venezuela, the genus remains poorly known. According to the most recent taxonomic account (Salazar-Bravo 2015), *Calomys* is composed of the following species: *C. boliviae* (Thomas 1901), *C. callidus* (Thomas 1916), *C. callosus* (Rengger 1830), *C. cerqueirai* Bonvicino, Oliveira and Gentile 2010, *C. expulsus* (Lund 1841); *C. hummelincki* (Husson 1960), *C. laucha* (Fischer 1914), *C. lepidus* (Thomas 1884), *C. musculinus* (Thomas 1913), *C. sorellus* (Thomas 1900), *C. tener* (Winge 1837), *C. tocantinsi* Bonvicino, Lima and Almeida 2003, *C. venustus* (Thomas 1894). In addition, at least three new species have been described in the last couple of years (Zeballos *et al.* 2014; Gurgel-Filho *et al.* 2015) and two more were resurrected from under the synonymy of *C. sorellus* (Zeballos *et al.* 2014), bringing the overall total to 18 currently recognized species.

The genus has a disjunct distribution with most species inhabiting grasslands, savannas, and forest edges from *ca.* latitude 8° S in the highlands of Peru and the Caatinga of Brazil to *ca.* latitude 16° S in central Bolivia, and from there south into Argentine Patagonia (Salazar-Bravo 2015). One species (*C. hummelincki*) occurs in grasslands and open habitat formations in northern South America (Colombia and Venezuela) and on the Netherland Antillean islands of Curaçao and Aruba (Martino *et al.* 2002; Salazar-Bravo 2015). Currently, eight species of *Calomys* are thought to occur in Brazil: *C. callidus*, *C. callosus*, *C. cerqueirai*, *C. expulsus, C. laucha*, *C. tener, C. tocantinsi,* and *C. mattevii* (see Paglia *et al.* 2012; Gurgel-Filho *et al.* 2015).

Herein we report the first record of Hummelinck's vesper mouse (*C. hummelincki*) from Brazil, based on a specimen obtained in an enclave of dry tropical savanna surrounded by rain forest in the state of Roraima.

Methods

The new specimen consists of a skin and skull (Figure 1) deposited in the mammal collections of Museu de Zoologia da Universidade de São Paulo (MZUSP 25729), São Paulo, Estado de São Paulo, Brazil. It is a young adult female (toothwear age class 3, *sensu* Voss 1991) collected on March 13, 1989 by C. M. Carvalho at Fazenda Salvamento, Estado de Roraima, Brazil. The specimen label indicates two embryos (preserved as MZUSP 25730).

According to C. M. Carvalho (2002), the MZUSP and Instituto Nacional de Pesquisa da Amazônia (INPA) made important expeditions to Roraima state between the years 1986 and 1991. Although the main effort was concentrated on herpetofauna, occasionally other groups were collected as well. Vanzolini and Carvalho (1991) described Fazenda Salvamento as a small cattle ranch located on the right bank of the Uraricoera River in northern Roraima state, Brazil (3.333° S, -61.400° W).

The collection site is within an area locally known as "lavrado", a local term used for the savannas that occur in the general area and that form part of the Rio Branco-Rupununi bioregion (see Voss 1991: figure 38). The topography of the region is dominated by interconnected streams ("igarapés") separated by small elevations, locally known as "tesos". The ground cover is predominately grasses surrounding rocky outcrops. The vegetation is usually sparse, except on top of the "tesos" (Vanzolini and Carvalho 1991; Carvalho and Carvalho 2012). The climate in this region is characterized by a rainy season from April/May to August/September and a dry season from October to March. Average temperatures range between 22° and 30° C. Annual rainfall for 1989 was 1,884 mm (see Vanzolini and Carvalho 1991; Carvalho 1992).

Figure 2. Right upper toothrow of *Calomys hummelincki* (MZUSP 25729).

Figure 1. Dorsal, ventral, and lateral views of the skull, and lateral view of the mandibles of *Calomys hummelincki* (MZUSP 25729).

Results

The new specimen is clearly a representative of the genus *Calomys* with body and skull measurements comparable only to those of *C. laucha*, *C. tener* and *C. hummelincki* (Table 1; see Bonvicino *et al.* 2010; Salazar-Bravo 2015). Moreover, based on the description in Salazar-Bravo (2015), MZUSP 25,729 exhibits all of the diagnostic external and craniodental characters of *C. hummelincki*, including grayish-orange dorsal pelage; mostly white ventral fur; distinct buffy post-auricular patches; weakly bicolored tail; short, narrow hind-feet covered with whitish hair; short and slender rostrum; shallow zygomatic notches; supraorbital region posteriorly divergent but not ridged; alisphenoid strut absent; greatest length of skull less than 21.0 mm; molar toothrow less than 3.3 mm (Figure 1). Other craniodental measurements for MZUSP 25,729 (Table 1) fall within the range of variation for this species.

Importantly, however, MZUSP 25,729 differs from other specimens of *C. hummelincki* in some traits, including a shallow (or absent) anteromedian flexus on M1 (versus a deeply divided M1 in individuals of the type series); presence of an anteromedian style, a trait present in fewer than 10 % of the specimens studied by Olds (1988); and a wider-than-average incisive foramen. Finally, MZUSP 25,729 has an upper molar series with molar proportions (M1:M2 and M2:M3) somewhat

Table 1. External and cranial measurements (in millimetres) of *Calomys hummelincki* specimens. Data are given as: minimum and maximum (Range), mean ($\bar{X}$), standard deviation (SD), and sample size (n). *New specimen; ** from Bekker (1999).

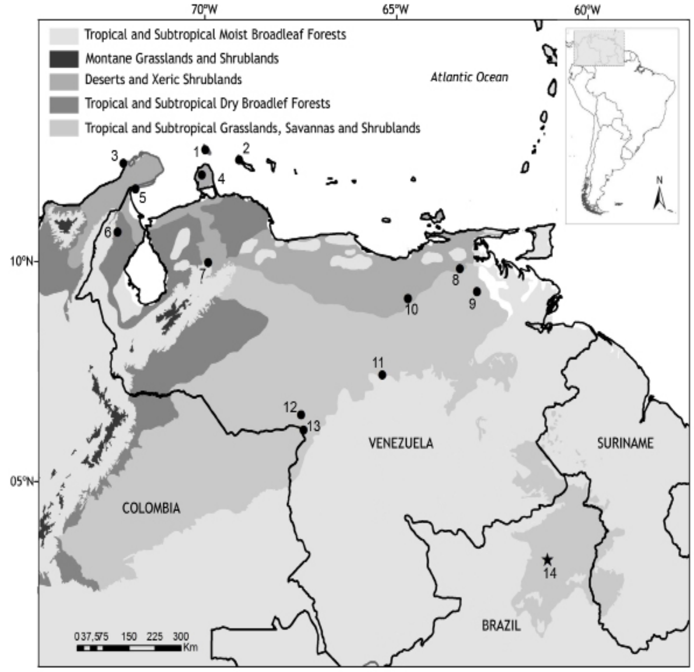
Traits	MZUSP 25729* ♀	♂ (*n* = 4)**		♀ (*n* = 3)**		Total (*n* = 8)**	
		Range	X̄ ± SD	Range	X̄ ± SD	Range	X̄ ± SD
Head and body	55.0	57.0 - 67.0	61.4 ± 4.7	55.0 - 63.0	58.3 ± 4.1	55.0 - 67.0	60.2 ± 4.5
Tail, without tuft	59.0	45.0 - 54.0	49.7 ± 3.7	45.0 - 51.0	48.0 ± 4.2	45.0 - 54.0	49.2 ± 3.6
Hind foot, without nail	15.0	13.4 - 13.7	13.5 ± 0.1	13.7 - 14.0	12.8 ± 0.2	13.4 - 14.0	13.7 ± 0.2
Ear, from notch	8.0	10.1 - 11.7	10.9 ± 0.6	10.3 - 11.2	10.7 ± 0.6	10.1 - 11.7	10.9 ± 0.6
Greatest skull length	18.3	-	-	-	-	-	-
Condylobasal length	16.6	16.2 - 18.9	17.6 ± 1.1	16.8 - 17.8	17.4 ± 0.5	16.2 - 18.9	17.6 ± 0.9
Basal length	14.9	15.2 - 16.7	16.1 ± 0.6	15.5 - 16.4	16.0 ± 0.4	15.2 - 16.7	16.1 ± 0.5
Palatinal length	8.6	9.0 - 10.3	9.6 ± 0.5	9.6 - 9.8	9.7 ± 0.1	9.0 - 10.3	9.6 ± 0.3
Incisive foramen length	3.6	3.8 - 4.7	4.3 ± 0.3	4.1 - 4.3	4.2 ± 0.1	3.8 - 4.7	4.2 ± 0.2
Nasal length	6.1	6.1 - 8.2	7.3 ± 0.8	6.7 - 7.5	7.1 ± 0.4	6.1 - 8.2	7.2 ± 0.6
Diastema	4.1	4.0 - 4.9	4.5 ± 0.3	4.5 - 4.7	4.6 ± 0.1	4.0 - 4.9	4.5 ± 0.2
Zygomatic breadth	(9.8)[1]	10.0 - 11.5	10.8 ± 0.6	10.2 - 10.8	10.5 ± 0.3	10.0 - 11.5	10.7 ± 0.5
Interorbital width	3.1	3.2- 3.5	3.3 ± 0.1	3.1 - 3.4	3.2 ± 0.1	3.1 - 3.5	3.3 ± 0.1
Upper molar row length	2.7	2.8 - 3.0	2.9 ± 0.0	2.9 - 3.0	2.9 ± 0.0	2.8 - 3.0	2.9 ± 0.1
Lower molar row length	2.8	3.2 - 3.5	3.3 ± 0.1	3.1 - 3.4	3.2 ± 0.1	3.1 - 3.5	3.3 ± 0.1
Mandible length	-	9.3 - 10.3	9.8 ± 0.4	9.5 - 10.0	9.8 ± 0.2	9.3 - 10.3	9.8 ± 0.3

[1] Approximated measurement, right zygomatic arch broken (see Figure 1).

different from those in populations farther north. Of special note is the proportionally larger M3 (*ca*. 75 % of M2) in the specimen from Roraima (Figure 2), when compared to *C. hummelincki* from other populations (*ca*. 70 % of M2).

Discussion and Conclusions

The new record reported here extends the distribution of the species about 630 km SE from the nearest previous record (Sipao, Estado Bolívar, Venezuela; Figure 3). Although the range of *C. hummelincki* is still disjunct with respect to those of other species of *Calomys* in South America, the new record considerably decreases the gap between them.



The current arrangement of vegetation communities north of the Amazon basin, where series of savannas are intermingled with forests, may be explained by the expansion and contraction of forest habitats during the Quaternary. The specific plant physiognomy dominating a particular area is influenced by a combination of soil, climate and elevation (Pennington *et al.* 2000; Vivo and Carmignotto 2004; Barbosa *et al.* 2007). We suggest that during drier periods, *C. hummelincki* expanded its distribution into northern South America along with the expansion of savanna vegetation formations. If, however, *C. hummelincki* evolved in the grasslands and savannas of northern South America, expanded distribution toward the south, offers a parsimonious biogeographic alternative. Either way, the population reported here is isolated from other populations of the species by a large tract of Tropical Moist Broadleaf Forest, no less than 130-km-wide, which separates the Gran Sabana/Rio Branco-Rupununi complex from the llanos. Nonetheless, future faunal assessments should be alert to the possible presence of *C. hummelincki* in the Ventuari and Esmeralda savannas of southern Venezuela.

Figure 3. Known records for *Calomys hummelincki* (modified from Salazar-Bravo 2015). The star represents the new record. Numbers in parentheses correspond to locality numbers on the map. Colombia: 1) Aruba, Sero Blanco, Colombia (12º 31′ N, -70º 01′ W); 2) Curaçao, Klein Santa Marta (12º 16′ 59″ N, -69º 07′ 59″ W); 3) Arroyo Cerrejón, Cabo de la Vela, La Guajira (12º 12′ 33″N, -72º 08′ 51″ W). Venezuela 4) Falcón, Isiro (11º 56′ 57″ N, -70º 05′ 58″ W); 5) Zulia, near Cojoro, 34 Km NE Paraguaipoa (11º 37′ 59″ N, -71º 49′ 59″ W); 6) Zulia, confluencia Río Lajas con El Palmar (10º 39′ 44″ N, -72º 17′ 54″ W); 7) Lara, Cuarigua (9º 58′ 43″ N, -69º 56′ 13″ W); 8) Monagas, 8 Km NW Los Barrancos (9º 50′ 18″ N, -63º 22′ 56″ W); 9) Monagas, Hato Mata de Brejuco, 55 Km SE (9º 19′ N, -62º 55′ 59″ W); 10) Anzoátehi, El Merey (9º 10′ N, -64º 43′ 59″ W); 11) Bolívar, Sipao (7º 26′ 35″ N, -65º 24′ 12″ W); 12) Río Cinaruco, 38 Km NW Puerto Paez (6º 33′ N, -67º 31′ W); 13) pure, Puerto Paez (6º 12′ 27″ N, -67º 27′ 04″W); Brazil: 14) Fazenda Salvamento, Roraima (3° 20′ N, -61° 24′ W).

Although the Roraima savannas currently lack legally protected areas for the conservation of biodiversity, about 46% of the territory in this region is under the protection of the State as Indigenous land. With few exceptions (*e. g.*, Barbosa *et al.* 2007), the mammal communities in the region are poorly known, especially as concerns small species such as marsupials, rodents, and bats. According to Voss (1991: table 30), only three out of nine non-forest mammals (*Zygodontomys brevicauda*, *Calomys hummelincki,* and *Cavia aperea*) occurring in northern South America are known from the Rio Branco-Rupununi savannas. Others, for example, *Dasypus sabanicola* and *Lutreolina crassicaudata,* are not known from the area, but are likely to occur there. This report, documenting the occurrence of *C. hummelincki* in this habitat, highlights the need to investigate and protect the biodiversity of the Rio Branco-Rupununi savannas. Further research on *Calomys* in this region is also needed to assess the genetic divergence of this isolated population.

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Literature cited

Barbosa, R. I., C. Campos, F. Pinto, and P. M. Fearnside. 2007. The "*Lavrados*" of Roraima: biodiversity and conservation of Brazil's Amazonian Savannas. Functional Ecosystems and Communities 1:29-41.

Bekker, J. P. 1999. The mammals of Aruba (Mammalia: Chiroptera, Rodentia, Lagomorpha). Vereniging voor Zoogdierkunde en Zoogdierbescherming. Utrecht, Netherlands.

Bonvicino, C. R., J. A. Oliveira, and R. Gentile. 2010. A new species of *Calomys* (Rodentia: Sigmodontinae) from southeastern Brazil. Zootaxa 2336:19-35.

Carvalho, C. M. 1992. Estrategias reprodutivas de duas espécies simpátricas de lagartos do gênero *Gymnophthalmus* de Roraima, Brasil (Sauria, Teiidae). PhD Dissertation. Instituto Nacional de Pesquisas da Amazônia, Fundação Universidade do Amazonas.

Carvalho, C. M. 2002. Descrição de uma nova espécie de *Micrurus* do Estado de Roraima, Brasil (Serpentes, Elapidae). Papéis Avulsos de Zoologia 42:183-192.

Carvalho, T. M., and C. M. Carvalho. 2012. Interrelation of geomorphology and fauna of Lavrado region in Roraima, Brazil – suggestions for future studies. Quaternary Science Journal 61:146–158.

Gurgel-filho, N. M., A. Feijó, and A. Langguth. 2015. Pequenos mamíferos do Ceará (marsupiais, morcegos e roedores sigmodontíneos) com discussão taxonômica de algumas espécies. Revista Nordestina de Biologia 23:3-150.

Martino, A. M. G., M. G. Filippucci, and E. Capanna. 2002. Evolutive pattern of *Calomys hummelincki* (Husson1960; Rodentia, Sigmodontinae) inferred from cytogenetic and allozymic data. Mastozoología Neotropical 9:187-197.

Olds, N**.** 1988. A revision of the genus *Calomys* (Rodentia: Muridae). PhD Dissertation. New York: City University of New York. New York, U. S. A.

Paglia, A.P., G. A. B., Fonseca, A. B. Rylands, G. Herrmann, L. M. S. Aguiar, and A. G. Chiarello. 2012. Lista Anotada dos Mamíferos do Brasil. Occasional papers in conservation Biology. Conservation Internacional, Arlington, U. S. A.

Pennington, R. T., D. E. Prado, and C. A. Pendry. 2000. Neotropical seasonally dry forest and Quaternary vegetation changes. Journal of Biogeography 27:261–273.

Salazar-Bravo, J. 2015. Genus *Calomys* Waterhouse, 1837. Pp.481-507 in Mammals of South America, volume 2: Rodents (Patton, J. L., U. F. J. Pardiñas, and G. D'Elía, (eds.). The University of Chicago Press, Chicago and London. Chicago, U. S. A.

Vanzolini, P. E., and C. M de Carvalho. 1991. Two sibling and sympatric species of *Gymnophtalmus* in Roraima, Brasil (Sauria, Teiidae). Papéis Avulsos de Zoologia 37:173-226.

Vivo, M., and A. P. Carmignotto. 2004. Holocene vegetation change and the mammal faunas of South America and Africa. Journal of Biogeography 31:943-957.

Voss, R. S. 1991. An introduction to the Neotropical muroid rodent genus *Zygodontomys*. Bulletin of the American Museum of Natural History 210:1–113.

Zeballos, H., R. E. Palma, P. A. Marquet, and G. Ceballos. 2014. Phylogenetic relationships of *Calomys sorellus* complex (Rodentia: Cricetidae), with the description of two new species. Revista Mexicana de Mastozoología (nueva época) 4:1–23.

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New record of bilateral hyperdontia in *Carollia brevicauda* (Chiroptera: Phyllostomidae)

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Systematics and taxonomy of bats is based in part on the morphological characteristics of the teeth and dental formulas. However, sometimes dental abnormalities appear that involve changes in the shape and number of teeth which can lead to erroneous taxonomic identifications. Numerous cases of dental anomalies have been reported for all groups of mammals, especially bats, the group with the most dental anomalies reported. This note presents a rare case of bilateral hyperdontia in *Carollia brevicauda*, for which only cases of oligodontia had previously been registered. The dental anomaly was found in a male specimen of silky short-tailed bat from the middle basin Rio Guayuriba, Acacias, Meta, Colombia. The unusual individual shows an additional incisor annexed to each normal external incisor in the maxilla, with separate alveoli, for a total of 6 upper incisors, two more than normal. The extra teeth have a morphology similar to the external incisors characteristic of the species, short and rounded, and are located between the canine and the second (external) upper incisor on each side of the head. No other specimen among 66 individuals of the same species showed a dental anomaly. This is the first record of bilateral hyperdontia for *C. brevicauda*. This dental anomaly may be due to an isolated mutation in this individual, because no other specimens with this type of anomaly were found in the study area.

La sistemática y taxonomía de los murciélagos está basada en parte sobre las características morfológicas de los dientes y sus fórmulas dentales. Sin embargo, a veces se presentan anomalías dentales que involucran cambios en la forma y número de los dientes lo cual puede llevar a identificaciones taxonómicas erróneas. Numerosos casos de anomalías dentales han sido reportados para todos los grupos de mamíferos, especialmente los murciélagos, el grupo con más anomalías dentales reportadas. Esta nota presenta un raro caso de hiperdontia bilateral en *Carollia brevicauda*, para el cual solamente casos de oligodontia han sido previamente registrados. La anomalía dental fue encontrada en un espécimen macho del murciélago de cola corta desde la cuenca media del Rio Guayuriba, Acacias, Meta, Colombia. El inusual individuo muestra un incisivo adicional anexo a cada incisivo externo normal en la maxila, con alveolos dentarios separados, para un total de seis incisivos superiores, dos más de lo normal. Los dientes extranumerarios tienen una morfología similar a los incisivos externos característicos de la especie, cortos y redondeados, y están localizados entre el canino y el segundo incisivo superior (externo) sobre cada rama maxilar. Ningún otro espécimen entre los 66 individuos de la misma especie mostró una anomalía dental. Este es el primer registro de hiperdontia bilateral para *C. brevicauda.* Esta anomalía dental puede deberse a una mutación aislada en este individuo, porque ningún otro espécimen con este tipo de anomalía fue encontrado en el área de estudio.

Keywords: bats; dental anomaly; incisor; polyodontia; supernumerary teeth.

Introduction

Systematics and taxonomy of bats is based in part on the morphological characteristics of teeth and dental formulas (Ramírez-Pulido and Müdespacher 1987; Rui and Drehmer 2004; Lanza *et al.* 2008; Cirranello *et al.* 2016). Abnormal dental formulas occur infrequently in natural populations of bats. However, when supernumerary teeth are present, the attendant changes in the shape and number of teeth can sometimes lead to erroneous taxonomic identifications.

There are mainly two types of anomalies in the number of teeth in mammals: polyodontia and oligodontia (López-Aguirre 2014). The first anomaly is rarer than the second (Lanza *et al.* 2008). Polyodontia, also called hyperdontia, hyperdoncia, third set of teeth, extra teeth, or polidontismo (Rodriguez and Cerviño 2009) can be caused by: 1) the creation and subsequent development of an additional tooth germ caused by expressions of rare genes. 2) The complete division of a tooth germ caused by mutations or changes in the genetic control of the development of teeth (Wolsan 1984). 3) By isolated mutations that could cause abnormalities to proteins such as Sonic hedgehog (*Shh*) that are responsible for normal development of molars and incisors, resulting in abnormal locations and stunted growth of these teeth (Dassule *et al.* 2000).

Numerous cases of dental anomalies have been reported for many groups of mammals, such as felids (*Lynx lynx*; Gomerčić *et al.* 2009), marsupials (*Dromiciops gliroides, Rhyncholestes raphanurus*; Martin 2007), cervids (*Cervus elaphus hispanicus*; Azorit *et al.* 2002), rodents (*Hystrix cristata, Necromys lasiurus*; Angelici and Luiselli 1999; Libardi and Percequillo 2014), pinnipeds (*Arctocephalus australis*, *A. tropicalis, Otaria flavescens*; Loch *et al.* 2010) and bats (*Artibeus lituratus, Epomophorus wahlbergi*; Rui and Drehmer 2004; Lanza *et al*. 2008) among others.

Bats are the group with most dental anomalies among mammals. López-Aguirre (2014) recorded 64 species of bats with dental anomalies, which predominate in insectivorous species, especially those belonging to the genus *Myotis*. The same author mentions that in the family Phyllostomidae, twenty-two species with dental anomalies have been reported, followed by Vespertilionidae and Pteropodidae with 18 and 17 species, respectively. This note presents a rare case of bilateral hyperdontia in *Carollia brevicauda*, a species whose characteristic dental formula (I 2/2, C 1/1, PM 2/2, M 3/3) is affected here in the normal number of incisors.

Material and methods

The specimen of *Carollia brevicauda* was collected during a study in the piedmont plains on the bat assembly of species present in the middle basin of the Rio Guayuriba, Acacias - Meta, Colombia. The catch was made in March 2014, in the village Portachuelos (4.18090° N, -73.80998° W) at 1,708 m elevation using mist nets set in a patch of tropical moist forest. Additionally, 25 bat species were recorded with *Carollia* being the most abundant genus with 197 captures. *C. brevicauda* was recorded on 66 occasions with 23 being collected, only one of which having the described dental anomaly. This individual was deposited in the Collection of Mammals of the Natural History Museum of the Francisco José de Caldas University (MHNUD) under catalog number 921.

Results

The aberrant individual has an additional incisor adjacent to each normal external incisor in the maxilla, with separate alveoli, for a total of six upper incisors, two more than normal (Figure 1). It is an adult male, and thus has a degree of cranial sutures with an advanced degree of ossification, and little wear on tooth cusps. However, the evidence from the following morphometric measurements (in mm) is sufficient to determine that it is an adult (Morris 1972): total length (TL): 64.0, wingspan (W): 309.0, forearm length (FA): 39.2, ear length (E): 18.6, noseleaf (N): 8.0, foot length (FL): 9.8, tibia: 13.0, calcaneus: 4.6 and body weight 18.6 g.

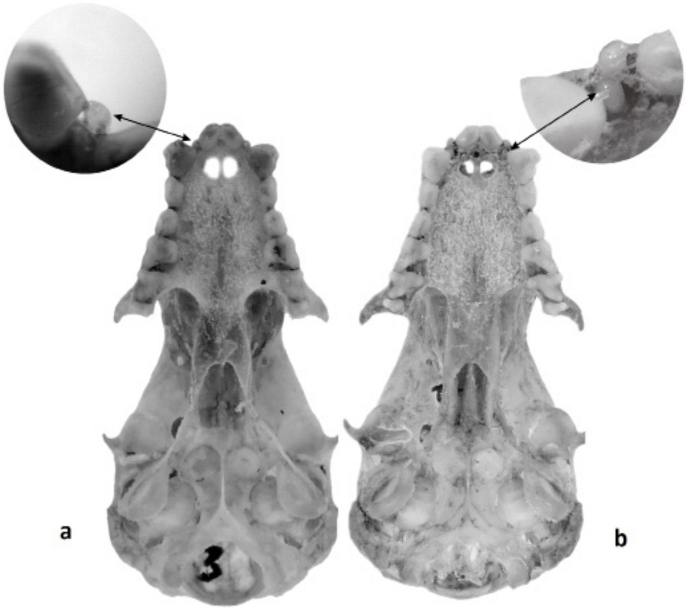

Figure 1. a) Ventral view of the cranium of specimen MUD 863, detailing the typical external incisors in Carollia brevicauda. b) Ventral view of the skull of specimen MUD 921, detailing the extranumerary incisors.

Discussion and conclusions

This is the first record of bilateral hyperdontia for this species. Previously, only cases of oligodontia had been reported for *Carollia brevicauda* (López-Aguirre 2014). The extra numerary teeth have a morphology similar to the external incisors characteristic of the species, short and rounded (Figure 1a) and are located between the canine and the second upper incisor (external) on each side of the upper jaw (Figure 1b).

This dental anomaly may be due to an isolated mutation present in this one individual, and without a permanent presence in the population since no other specimens with this type of anomaly were found in the study area. More likely, this is an example of the reappearance of an ancestral trait (atavism) caused by a shift in developmental patterning.

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Literature cited

Angelici, F. M., and L. Luiselli. 1999. Extra teeth and dental anomalies in the crested porcupine *Hystrix cristata*, from Sicily. Acta Theriologica 44:219-223.

Azorit, C., Muñoz-cobo, J., and M. Analla. 2002. Abnormal teeth in the Spanish red deer (*Cervus elaphus hispanicus*). Zeitschrift für Jagdwissenschaft 48:252-260.

Cirranello, A., N. B. Simmons, S. Solari, and R. J. Baker. 2016. Morphological diagnoses of higher-level phyllostomid taxa (chiroptera: phyllostomidae). Acta Chiropterologica 18:39-71.

Dassule, H. R., P. Lewis, M. Bei, R. Maas, and A. P. Mcmahon. 2000. Sonic hedgehog regulates growth and morphogenesis of the tooth. Development 127:4775-4785.

Gomerčić, T., G. Gužvica, M. Duras, J. Kusak, M. Sindičić, and D. Huber. 2009. Variation in teeth number, teeth and skull disorders in Eurasian lynx, *Lynx lynx* from Croatia. Folia Zoological 58:57-65.

Lanza, B., Riccucci, M., and U. Funaioli. 2008. An interesting case of polyodontia in *Epomophorus wahlbergi*, with a review of this dental anomaly in bats (Chiroptera). Lynx series nova 39:109-127.

Libardi, G. S., and A. R. Percequillo. 2014. Supernumerary teeth in *Necromys lasiurus* (Rodentia, Cricetidae): the first record in sigmodontinae. Mastozoología neotropical 21:219-229.

Loch, C., P. C. Simões-Lopes, and C. J. Drehmer. 2010. Numerical anomalies in the dentition of southern fur seals and sea lions (Pinnipedia: Otariidae). Zoologia (Curitiba) 27:477-482.

Lopez-Aguirre, C. 2014. Dental anomalies: New cases of *Artibeus lituratus* from Colombia and a review of these anomalies in bats (Chiroptera). Chiroptera Neotropical 20:1271-1279.

Martin, G. M. 2007. Anomalías en la dentición de *Dromiciops gliroides* (Microbiotheria, Microbiotheriidae), *Caenolestes fuliginosus* and *Rhyncholestes raphanurus* (Paucituberculata, Caenolestidae). Revista Chilena de Historia Natural 80:393-406.

Morris, P. 1972. A review of mammalian age determination methods. Mammal Review 2:69-104.

Ramírez-pulido, J., and C. Mudespacher. 1987. Formulas dentarias anormales en algunos murciélagos mexicanos. Acta Zoológica Mexicana (n. s.) 23:1-54.

Rodríguez Romero, F. J., and S. Cerviño Ferradanes. 2009. Múltiples dientes supernumerarios distomolares. Avances en Odontoestomatología 25:319-325.

Rui, A. M., and C. J. Drehmer. 2004. Anomalías e variações na fórmula dentária em morcegos do gênero *Artibeus* Leach (Chiroptera, Phyllostomidae). Revista Brasileira de Zoología 21:639-648.

Wolsan, M. 1984. The origin of extra teeth in mammals. Acta Theriologica 29:128-133.

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Notable altitudinal range expansion of *Lontra longicaudis* (Carnivora: Mustelidae) in Colombian Paramos

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The neotropical otter *Lontra longicaudis* is a carnivore that ranges from Mexico to northern of Argentina, from 0 to 3,885 m above the sea level. In Colombia, this mammal is considered a research priority due the poor information about its distribution and basic ecology. The aim of this note is to contribute to the knowledge of the altitudinal distribution of *L. longicaudis* in the Mamapacha Paramos, Boyacá, Colombia. Camera trap fieldwork was carried out from November 18th to December 7th of 2015 in the department of Boyacá on the Cordillera Oriental, Colombia. Additionally, we reviewed preserved specimens and historical records of sightings above 2000 m in several scientific publications on *L. longicaudis*. Of the 275 images of wildlife, four images corresponded to *L. longicaudis* at the Mundo Nuevo lagoon, municipality of Chinavita (3,110 m above sea level). After the literature and museum specimens review, we found that there were no records of *L. longicaudis* in Colombia that exceeded 3,000 m above sea level. Therefore, our record represents a notable altitudinal range expansion of *L. longicaudis* and a new altitudinal level record for the species in Colombia. This record can be a consequence of the abundant food supply provided by the Rainbow trout (*Oncorhynchus mykiss*). Due to the competition between otters and local people by the trout, it is necessary to implement management plans of fish resources in order to mitigate human-otter conflict and to ensure the population viability at Mundo Nuevo Lagoon.

La nutria neotropical *Lontra longicaudis* es un carnívoro, que se distribuye desde México hasta el norte del Argentina, entre 0 y 3,885 m sobre el nivel del mar. En Colombia la especie es considerada como prioridad de investigación debido al escaso conocimiento sobre ecología y distribución. Con el fin de contribuir al conocimiento sobre *L. longicaudis* en Colombia, esta nota presenta un nuevo registro altitudinal de la especie para el Páramo de Mamapacha en Boyacá, Colombia. Se realizó un estudio de fototrampeo entre el 18 de Noviembre al 7 de Diciembre del 2015 en el departamento de Boyacá en la Cordillera Oriental en Colombia. Adicionalmente, se realizó una búsqueda de especímenes preservados y registros en publicaciones científicas de *L. longicaudis*, considerando registros por encima de los 2,000 m sobre el nivel del mar. De un total de 275 imágenes de fauna obtenidas, se registraron cuatro de *L. longicaudis* para la Laguna de Mundo nuevo en el municipio de Chinvita a 3,110 m sobre el nivel del mar. Los registros encontrados en la revisión de literatura y ejemplares de museos, no superan los 3,000 m de altitud y en su mayoría proceden de la cordillera occidental, lo que confirma que nuestro registro representa una expansión en la distribución altitudinal y el registro más alto para la especie en Colombia. Este registro puede deberse a la abundante fuente de alimento que representa la Trucha Arcoiris (*Oncorhynchus mykiss*). Debido a que la trucha es un recurso que genera competencia directa entre la nutria y la población humana es necesario implementar planes de manejo del recurso pesquero con el fin de mitigar el conflicto nutria-humano y asegurar la viabilidad poblacional de la especie en el área.

Key words: Boyacá; distribution; neotropical otter; Paramo; rainbow trout

Introduction

The Neotropical otter or "perro de agua" *Lontra longicaudis* is a carnivore of the Mustelidae family. As well as its congeners, *L. longicaudis* is an opportunistic predator that consumes fish (its main diet component), crustaceans, mollusks, birds, reptiles, small mammals and insects (Helder and Ker de Andrade 1997). It ranges from northern Mexico to northern Argentina in the province of Buenos Aires, with altitudinal distribution between 0 and 3,885 m above the sea level (Emmons and Feer 1997; Castro-Revelo and Zapata-Ríos 2001). However, its altitudinal range of preference is between 300 to 1,700 m (Larivière 1999). *L. longicaudis* is the most common otter in Colombia, where it inhabits the evergreen forest, rain forest and savannas associated to fresh water ecosystems (Larivière 1999; Calderón-Capote *et al.* 2015). The Neotropical otter has low tolerance to transformed habitats. However, Trujillo and Arcila (2006) reported the presence of *L. longicaudis* on rivers with highly anthropic disturbances. Most of the published studies in Colombia have been carried out in the trans-Andean region. The most common topics for these studies include habitat use and diet (Mayor-Victoria and Botero-Botero 2010a, b), trophic ecology of some populations that occur at Cauca and Quindio departments (Restrepo and Botero-Botero 2012), and range expansion at Putumayo (Noguera-Urbano and Montenegro-Muñoz 2011). Also, several records of *L. longicaudis* have been mentioned in regional and national mammal lists, which are based on personal observations, museum specimens records and literature compilations (see, Ferrer-Pérez *et al.* 2009; Ramírez-Chaves and Noguera-Urbano 2010; Solari *et al.* 2013). Nevertheless, large areas of Colombia are lacking intensive sampling, especially the Andean highlands, and particularly the Paramos of the Cordillera Oriental. Therefore, *L. longicaudis* is considered a research priority due the poor information about its presence and abundance in the country (González-Maya *et al.* 2011). The aim of this paper is to gain insights on the altitudinal distribution of *L. longicaudis* in the Colombian Paramos of Boyacá, Colombia.

Materials and Methods

Fieldwork was carried out in the municipalities of Chinavita, Garagoa and Viracachá, department of Boyacá on the eastern slopes of the Cordillera Oriental. The sampling stations were located in Andean forest, Paramo and the ecotone between these ecosystems. Surveys were conducted between November 18th to December 7th of 2015, using 12 camera-traps (four ScoutGuard SG550V and eight Bushnell 8MP Trophy Cam Standard). Each camera-trap was considered as a track sampling unit. The cameras were placed at 50 cm of the floor, near places with animal trails, traces, feeding places, refuges or ecotones between the Paramo and the Andean forest. The sampling effort was of 4,320 h of camera-recording, and each sampling station was baited at the first day of the survey during eight days with 160 g of sardines. Additionally, for comparative purposes, preserved specimens housed in Colección de Mamíferos Alberto Cadena García, Instituto de Ciencias Naturales of Universidad Nacional de Colombia (ICN) were examined. Also, historical records of *L. longicaudis* in scientific publications and museums were consulted, with emphasis on record sightings above 2,000 m.

Results

A total of 275 images of wildlife were recorded, of which four pictures were of *L. longicaudis*. All records came from the station Mundo Nuevo Lagoon at the municipality of Chinavita (3,110 m; Figure 1). These camera traps were placed over the edge of the Mundo Nuevo lagoon which is surrounded by shrubbery vegetation and frailejones (*Espeletia* spp.). The first and second images were taken on November 27 at 20:03 and 20:17 respectively. These pictures show one specimen of *L. longicaudis* approaching the bait. The third and fourth images were taken on November 28 at 06:57 and 09:03 respectively. In these occasions the pictures show one specimen approaching the camera-trap. Features such as sex and age cannot be distinguished from the individuals photographed (Figure 2). These images were taken in areas where otter scats and fish remains were found.

Rojas-Diaz *et al.* (2012) reported the presence of *L. longicaudis* at 3,000 m at both slopes of the Cordillera Occidental. However, that record was not confirmed due that it lacks the specific locality and collection number. Only seven specimen sightings at 2,000 m or above were found on the literature and museum records (Table 1). The highest altitude reported was 2,700 m (Ramírez-Chaves and Noguera-Urbano 2010), which confirms that our record represents an altitudinal range expansion of *L. longicaudis* as well as the maximum altitude recorded for the species in Colombia.

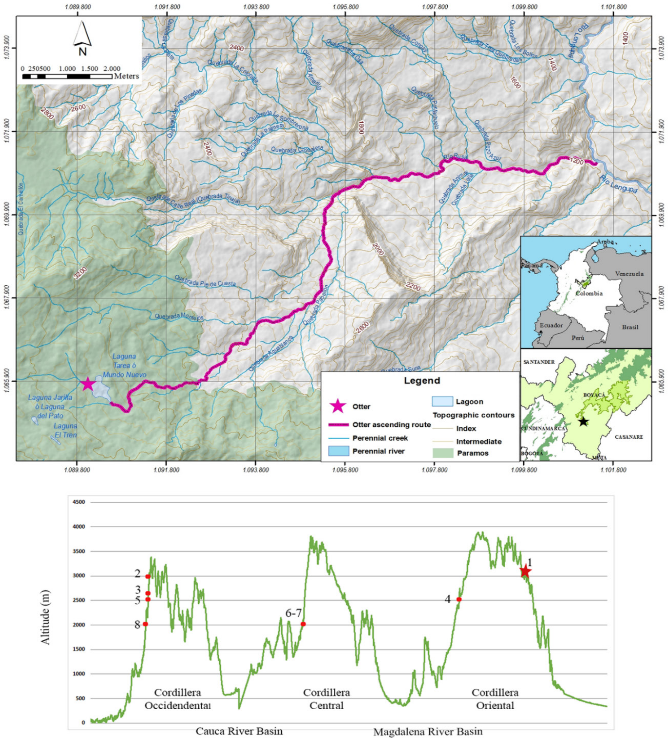

Figure 1. Record of Neotropical otter at Chinavita Municipality that extends their altitudinal range. Possible otter ascending route with the altitudinal profile of records above 2,000 m in Colombia based on our records and those from the literature and preserved specimens. 1. This study; 2. Rojas-díaz *et al.* 2012; 3. Ramírez-Chaves and Noguera-Urbano 2010; 4. FMNH 146397; 5. FMNH 8848; 6. Mayor-Victoria and Botero-Botero 2010 a; 7. Mayor-Victoria and Botero-Botero 2010 b; 8. Corantioquia / 8110002317-09. Cordillera Occidental cut west to east over south of Cauca department with 135 degrees. Cordillera Central cut west to east over Valle del Cauca through south Quindío Department, with 138 degrees. Cordillera Oriental cut west to east over Tolima department to North of Meta department.

Discussion

The niche partitioning theory states that the presence of carnivores is associated directly with their prey abundance and presence (Sunquist and Sunquist 1989). The altitudinal range expansion of *L. longicaudis* from Mamapacha's Paramo at 3,110 m might supports this hypothesis. Commonly, this species inhabits riverine ecosystems between 0 to 1,700 m that provide a wide range of food availability (Larivière 1999). However, Guerrero-Flores *et al.* (2013) indicate that *L. longicaudis* is an opportunistic predator with a broad food spectrum that allows it to move outside of its preference range when abundant food supply is available. Therefore, the altitudinal range expansion of *L. longicaudis* can be a consequence of an abundant food supply, provided by the Rainbow trout (*Oncorhynchus mykiss*), an introduced species that inhabits the high mountain lagoons at Mamapacha Paramos.

The rainbow trout was introduced on Boyacá high mountain lagoons about 90 years ago with the goal to use them in artisanal and sport fisheries (Parrado-Sanabria 2012). As a result, many rainbow trout fisheries were established throughout the region of Mundo Nuevo village. Due to the generalist diet and predator characteristics of Rainbow trout, it became the dominant and most abundant species of fish on the high mountain lagoons (Martín-Torrijos *et al.*

Table 1. Altitudinal records of *L. longicaudis* above 2000 m in Colombia.

ID	Autor/Museum	Year	Departament	Municipality	Locality	coordinates	altitude (masl)
1	This note	2015	Boyacá	Chinavita	Mundo nuevo Lagoon	5° 11′ 28″ N, -73° 15′ 55″ W	3,110
2	Rojas-Díaz *et al.*	2012	Valle del Cauca	----	----	----	3,000
3	Ramírez-Chaves and Noguera-Urbano	2010	Nariño	----	----	----	2,700
4	FMNH 146397	----	Cundinamarca	Bogotá, D.C	Bogotá D.C.	4° 37′ 0″ N, -74° 5′ 60″ W	2,565
5	FMNH 88481	1957	Cauca		Munchique	2° 31′ 60″ N, -76° 57′ 0″ W	2,524
6	Mayor-Victoria and Botero-Botero	2010a	Quindío	----	Near Reserva Natural La montaña del Ocaso	4° 41′ 0″ N, -75° 26′ 0″ W	2,100
7	Mayor-Victoria and Botero-Botero	2010b	Quindío	----	Rio roble	4° 41′ 0″ N. -75° 26′ 0″ W	2,100
8	Corantioquia / 8110002317-09	----	Antioquia	Jericó	----	5° 47′ 60″ N, -75° 47′ 24″ W	2,000

2016). Therefore, the rainbow trout is an abundant food supply that might encourage otters to move from lowlands to highlands. This pattern agrees with reports by Monroy-Vilchis and Mundo (2009), and Guerrero-Flores *et al.* (2013) who found that colonization of high mountain ecosystem in Mexico by *L. longicaudis* is related to the invasive species abundance, which in some cases, represents almost 100 % of the otter diet. Likewise, Castro-Revelo and Zapata-Ríos (2001) have reported *L. longicaudis* at 3,885 m in Ecuador, pointing out that they found fish remains associated to the diet of the otter, however, they not specified whether they belong to native or introduced species. Whereby, more diet preference and prey abundance studies are needed in order to verify whether the altitudinal range increase of *L. longicaudis* is due to this food availability provided by the trout (Briones-Salas *et al.* 2013; Guerrero-Flores *et al.* 2013).

Additionally, based on landscape cover and the drainage connectivity. We hypothesize the possible ascending route used by *L. longicaudis* to reach the Mundo Nuevo Lagoon (Figure 1). First, the possible population source might have been located at Batatá dam (1,042 m). Second, the ascending route might have started from Batatá dam, through La Rusa River, through Canelo creek until reaching to Mundo Nuevo Lagoon. Moreover, a robust sampling effort must be encouraged to understand the size and distribution of *L. longicaudis* populations in the rivers and creeks of the municipalities of Chinavita, Garagoa and Viracachá.

Finally, the Mundo Nuevo Lagoon local farmers have noticed the presence of *L. longicaudis* for decades, following the introduction of rainbow trout and the establishment of trout fisheries in the area. Also, they suggest that the otter population might be of about five to six individuals. But the actual number of otters that inhabits the area is unknown. The highland population of *L. longicaudis* might be threatened by local farmers because they are in direct competition for the trout, as prey for the otters and food supply or income to the farmers. Hence, Neotropical otters are considered as a pest by local fishermen, some otters have been chased and killed to diminish the otter population.

Figure 2. Records of *L. longicaudis* from municipality of Chinavita at 3,110 m a) Third record at 06:54, on November 28. b) Fourth record at 09:03, on November 28.

This note presents the highest altitude record of *L. longicaudis* in Colombia, contributing to the knowledge of neotropical otter distribution in Boyacá Paramos. Likewise, our observation suggests that altitudinal range expansion record might be associated with the prey availability that represents the introduction of Rainbow trout and the development of a trout fishery at the Paramos lagoons. However, more diet studies on the otters at Mundo Nuevo Lagoon are required to verify this hypothesis. On the other hand, conservation strategies together with environmental education are needed in order to reduce human-otter conflict.

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Literature cited

Briones-Salas, M., M. A. Peralta-Pérez and E. Arellanes. 2013. Análisis temporal de los hábitos alimentarios de la nutria neotropical (*Lontra longicaudis*) en el rio Zimatán en la costa de Oaxaca, México. Therya 4:311-326

Calderón-Capote, M. C., A. V. Rojas-Rojas, C. Cárdenas-González And A, Pardo-Martínez. 2015. Familia Mustelidae. Pp. 110-135, in Los carnívoros terrestres y semiacuáticos continentales de Colombia: Guía de Campo (Suárez-Castro, A. F., and H. E. Ramírez-Chaves, eds.). Universidad Nacional de Colombia. Bogotá, Colombia.

Castro-Revelo, I., and G. Zapata-Ríos. 2001. New altitudinal record for *Lontra longicaudis* (Carnivora: Mustelidae) in Ecuador. Mammalia 65:237–239.

Emmons, L. H., and F. Feer. 1997**.** Neotropical rainforest mammals: a field guide. The University of Chicago Press. Chicago, U. S. A.

González-Maya, J. F., A. A., Cepeda, J. L., Belant, D. A., Zárrate-Charry, S. A., Balaguera-Reina, and A., Rodríguez-Bolaños. 2011. Research priorities for the small carnivores of Colombia. Small Carnivore Conservation 44:7-13.

Guerrero-Flores, J. J., S., Macías-Sánchez, V., Mundo-Hernández, and F. Méndez-Sánchez. 2013. Ecología de la nutria (*Lontra longicaudis*) en el municipio de Temascaltepec, Estado de México: estudio de caso. Therya 4:231-242.

Helder, J., and H. Ker de Andrade. 1997. Food and feeding habits of the neotropical river otter *Lontra longicaudis* (Carnivora, Mustelidae). Mammalia 61:193-204.

Larivière, S. 1999. *Lontra longicaudis*. Mammalian Species 609:1-5.

Martín-Torrijos, L., J. V. Sandoval-Sierra, J. Muñoz, J. Diéguez-Uribeondo, J. Bosch, and J. M. Guayasamin. 2016. Rainbow trout (*Oncorhynchus mykiss*) threaten Andean amphibians. Neotropical Biodiversity 2:26-36.

Mayor-Victoria, R., and A. Botero-Botero. 2010a. Dieta de la nutria neotropical *Lontra longicaudis* (Carnívora, Mustelidae) en el río Roble, Alto Cauca, Colombia. Acta Biológica Colombiana 15:237-244.

Mayor-Victoria, R., and A. Botero-Botero. 2010b. Uso del hábitat por la nutria neotropical *Lontra longicaudis* (Carnivora: Mustelidae) en la zona baja del río Roble, Alto Cauca, Colombia. Boletín Científico Centro Museos Historia Natural 14:121-130.

Monroy-Vilchis, O., and V. Mundo. 2009. Nicho trófico de la nutria neotropical (*Lontra longicaudis*) en un ambiente modificado, Temascaltepec, México. Revista Mexicana de Biodiversidad 80:801-806.

Noguera-Urbano, E. A. and S. Montenegro-Muñoz. 2011. Primer registro de la nutria tropical o lobito de río (*Lontra longicaudis* Olfers 1818) en el Piedemonte Andino-Amazónico y comentarios sobre la distribución en Putumayo Colombia. Novedades Colombiana 11:19-25.

Parrado-Sanabria, Y. A. 2012. Historia de la Acuicultura en Colombia. AquaTIC 37:60-77.

Ferrer-Pérez, A. F., M. B., Gutiérrez, and C. A., Lasso. 2009. Mamíferos de la Estrella Fluvial de Inírida: ríos Inírida, Guaviare, Atabapo y Orinoco (Colombia). Biota Colombiana 10:209-218.

Ramírez-Chaves, H. E., and E. A. Noguera-Urbano. 2010. Lista preliminar de los mamíferos (Mammalia: Theria) del departamento de Nariño, Colombia. Biota Colombiana 11:117-140.

Restrepo, C., and A. Botero-Botero. 2012. Ecología trófica de la nutria neotropical *Lontra longicaudis* (Carnivora, Mustelidae) en el río La Vieja, alto Cauca, Colombia. Boletín Científico del Museo de Historia Natural Universidad de Caldas 16:207-214.

Rojas-Díaz, V., M. Reyes-Gutierrez and M. S. Alberico. 2012 Mamíferos (Synapsida, Theria) del Valle del Cauca, Colombia. Biota Colombiana 13:99-116.

Solari, S., Y. Muñoz-Saba, J. V. Rodríguez-Mahecha, T. R. Defler, H.E. Ramírez- Chaves and F. Trujillo. 2013. Riqueza, endemismo y conservación de los mamíferos de Colombia. Mastozoología Neotropical 20:301-365.

Sunquist, M. E., and F. C. Sunquist. 1989. Ecological constraints on predation by large felids. Pp. 283-301, in Carnivore behavior, ecology, and evolution (Gittleman J. L., eds.) Springer. Ithaca, U.S.A.

Trujillo, F., and D. Arcila. 2006. Nutria neotropical *Lontra longicaudis*. Pp: 249-254, in Libro rojo de los mamíferos de Colombia (Rodríguez-Mahecha, J. V., M. Alberico, F. Trujillo, and J. Jorgenson, eds.). Conservación Internacional Colombia, Ministerio de Ambiente, Vivienda y Desarrollo Territorial. Bogotá, Colombia.

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Noteworthy record of the kit fox (*Vulpes macrotis*) and its relation to physiographic characteristics in Baja California, Mexico

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The kit fox (*Vulpes macrotis*) lives in sandy and shallow soils of the Pacific coastal plains and the ecoregion of San Felipe desert. The reports of this species are scarce and in Mexico it is listed as a threatened species. The populations of *V. macrotis* tend to decrease due to the change in the habitat to agricultural land, which has been one of the causes of the disappearance of kit fox populations in Mexico. As part of the project "Characterisation of water bodies in Sierra Santa Isabel, Baja California", 12 camera traps were placed in six watering holes that are visited by wildlife from January to August 2015. Digital terrain elevation models were used to describe three variables: roughness, slope inclination and orientation; these variables are essential for the kit fox to build its burrows, catch its preys and escape from predators. The analyses were also carried out in localities where this carnivore had previously been recorded in Baja California. An analysis of variance was used to determine the existence of similarities or differences between the topographical characteristics of the historical localities and the new record. The first photographic record of the kit fox was obtained in one of the watering holes located within the Valle de los Cirios Flora and Fauna Protection Area. The analyses of variance confirmed that there are no significant differences between roughness ($F_{(4, 780)} = 0.11$, $P > 0.05$), slope inclination ($F_{(4, 1275)} = 0.319$, $P > 0.05$) and orientation ($F_{(4, 15)} = 0.41$, $P > 0.05$), between the historical localities and the site where the new record was obtained. Other carnivores were also recorded in the watering hole, such as the cougar (*Puma concolor*), bobcat (*Lynx rufus*), coyote (*Canis latrans*) and gray fox (*Urocyon cinereoargenteus*). The presence of the kit fox is likely occasional in the watering hole, because the slopes are greater than 10 degrees and, therefore, these sites are unsuitable for the construction of burrows. However, flat sites with sandy substrates that empty into the Gulf of California occur at a distance of less than 5 km from the watering hole, which are therefore suitable to be inhabited by the kit fox. The analysis of topographic variables of the historical records coupled with camera traps jointly confirmed that the site with the new record has characteristics that are suitable for the kit fox.

La zorra norteña (*Vulpes macrotis*) habita en los suelos arenosos y pocos profundos de las planicies costeras del pacifico y de la ecorregión del desierto de San Felipe. Los reportes de esta especie son escasos y en México esta enlistada como una especie amenazada. Las poblaciones de *V. macrotis* tienden a disminuir por la transformación del hábitat a tierras agrícolas, la cual ha sido una de las causantes de la extirpación de poblaciones de zorra norteña en México. Como parte del proyecto "Caracterización de los cuerpos de agua en Sierra Santa Isabel, Baja California", se colocaron 12 cámaras trampa en seis aguajes que son visitados por la fauna silvestre de enero a agosto de 2015. Mediante modelos digitales de elevación del terreno se describieron tres variables: rugosidad, pendiente y orientación de las laderas, estas variables son esenciales para que la zorra norteña construya sus madrigueras, capture a sus presas y escape de sus depredadores. Los análisis también se realizaron en localidades que previamente se había registrado a este carnívoro en Baja California. Por medio de un análisis de varianza de una vía se determinó si existen similitudes o diferencias entre las características topográficas de las localidades históricas y el nuevo registro. En uno de los aguajes que se ubica dentro del Área de Protección de Flora y Fauna Valle de los Cirios, se obtuvo el primero registro fotográfico de la zorra norteña. Con los análisis de varianza se confirmó que no hay diferencias significativas entre la rugosidad ($F_{(4, 780)} = 0.11$, $P > 0.05$), pendiente ($F_{(4, 1275)} = 0.319$, $P > 0.05$) y orientación ($F_{(4, 15)} = 0.41$, $P > 0.05$), entre las localidades históricas y el sitio donde se obtuvo el nuevo registro. En el aguaje también se registraron otro carnívoros, como el puma (*Puma concolor*), gato montés (*Lynx rufus*), coyote (*Canis latrans*) y zorra gris (*Urocyon cinereoargenteus*). La presencia de la zorra norteña posiblemente es ocasional en el aguaje, debido a que las pendientes en el lugar son mayores a 10 grados y por lo tanto estos sitios no son idóneos para la construcción de madrigueras. Sin embargo, a una distancia menor a 5 km del aguaje se encuentran sitios planos con sustratos arenosos que desembocan al Golfo de California, y por lo tanto son idóneos para que la zorra norteña sea residente de esos lugares. Analizando variables topográficas de los registros históricos y mediante fototrampeo se confirmó que el sitio con el nuevo registro tiene características idóneas para la presencia de la zorra norteña.

Introduction

The kit fox is distributed in the northeastern central highlands in Mexico and the Baja California peninsula. The habitat of this species is the desert with xeric scrubland and sandy soils in the Sonoran and Baja California Desert (Álvarez-Castañeda 2000; Alvarez-Castañeda *et al.* 2008). Based on its conservation status according to NOM-059-2010 of SEMARNAT, this species is listed as threatened.

In Baja California, the records of the desert fox are scarce (Álvarez-Castaneada *et al.* 2015). Huey (1964) mentions the following localities where they this species has been collected and recorded in the state: Valle de la Trinidad (31.38° N, -115.65° W) as the highest-altitude collection site (834 m); the other locality is San Felipe (31.09° N, -114.97° W), where Huey collected specimens that are preserved in the San Diego Natural History Museum (SDHM). Another relevant locality in the state of Baja California is La Ventana (31.78° N, -115.08°W), where a fur was collected and there are records of photographic that can be consulted in the vertebrate collection of Universidad Autónoma de Baja California (UABC-572). All these sites are located to the north part of the state, while for the central and southern regions a single skull has been collected dating back to 1970 in Bahía Los Angeles (28.98° N, -113.53° W); the material is safeguarded in the mammals collection of the California Academy of Science (CAS-AM15692). This collection is the only record within the Valle de los Cirios Flora and Fauna Protection Area (APFFVC), which is the largest in Mexico (2,521,776 hectares), and according to the management program of this protected area, there is potentially suitable habitat for this species (Valle de los Cirios Flora and Fauna Protection Area 2013).

Materials and Methods

As part of the project "Characterisation of water bodies in Sierra Santa Isabel, Baja California", financed by the *JiJi Foundation*, 12 *Bushnell HD* camera traps were placed in six watering holes from January to August 2015. Cameras were programed to operate 24 hours and make three photographs and a 5-second video when movement was detected. The sampling effort was estimated by multiplying the number of cameras by the total number of trap nights.

The vegetation in the flat sampling sites and hills consists of xerophitic shrubland with the following dominant species: *Larrea tridentata*, *Prosopis microphylla, Cercidium microphyllum* and *Pachycereus discolor.* In the riverbanks and watering holes, the dominant species are: *Psorothamnus spinosus, Tamarix ramosissima, Lupinus excubitus, Encelia farinosa, Juncus acutus* (González-Abraham *et al.* 2010). The climate is semi-warm, with maximum temperatures of 45 °C in the summer. The mean annual precipitation in the slopes close to the Gulf of California is less than 50 mm, while in the central and northern parts of the sierra the precipitation ranges between 100 and 150 mm (Roberts and Ezcurra 2012).

The similarities between habitats where *V. macrotis* has been registered were determined by analyzing three topographic variables: slope inclination, orientation and roughness. These variables are associated with the sites where this species has its burrows, feeds and avoids predators (Warrick and Cypher 1988). These were calculated by means of digital terrain elevation models (MDT) with a 30-meter resolution. These were obtained from the United States Geological Survey (USGS) webpage. The models were generated from synthetic aperture radar images acquired during the SRTM Shuttle Radar Topography Mission mission (NASA).

Digital terrain elevation models were processed using the *Quantum GIS* program (QGIS Development Team 2016). The terrain analysis functions were used for calculating the terrain slope inclination, orientation and roughness. The calculation corresponds to a radius of 5 km around each record available for the kit fox. This area covers the minimum home range registered for this species (Zoellick *et al.* 2002). The slope inclination was measured in degrees, and the orientation was classified into four classes: northeast (0° to 90°), northwest (91° to 180°), southwest (181° to 270°), and southeast (271° to 360°). The terrain roughness was interpreted as follows: sites with values lower than 30 indicate flat sites with low hills; between 31 to 45, medium sierras with ravines; values greater than 50, high sierras with ravines and steps (Riley *et al.* 1999; Cyper *et al.* 2013). The values of the topographic variables obtained for each locality were analyzed using a one-way analysis of variance (ANOVA) in the R *Statistics* software (R Core Team 2013).

Results

A sampling effort of 2,880 days/trap yielded 870 videos and 1,369 photographs of birds, mammals and reptiles. Two of them recorded *V. macrotis* in El Junco (29.96° N, -114.70° W) at 00:13 and 00:55 hrs on 26 June 2015 (Figure 1). El Junco is located in Los Vascos basin that empties into the Gulf of California and is characterized by permanent springs all year round. (Figure 2). In addition, records of coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), and cougar (*Puma concolor*) were also obtained at El Junco.

The ANOVA for each topographic variables indicate that there are no significant differences between the values of the slope inclination ($F_{4,\ 1275} = 0.319$, $P > 0.05$), orientation ($F_{4,\ 15} = 0.41$, $P > 0.05$), and roughness ($F_{4,\ 780} = 0.11$, $P > 0.05$) between the historical localities and the new record of the kit fox in Baja California. The average value of the slope in El Junco was 34.24°, with minimum values of 0.35° and maximum of 70.01°. The values of terrain roughness correspond to flat and low mountain ranges that represented 58.28 % (1.323 pixels) of the total area (Figure 3). The lower values of slope and roughness were obtained for Bahía Los Angeles and La Ventana (Table 1). Slope orientation was similar in all locations, with the northwest as the most frequent orientation on average (Table 1).

Discussion

El Junco is characterized for being an isolated site with virtually no impact by anthropogenic activities. Rocky substrates in streams and slopes are not the type habitat for *V. macrotis*, although there are some records in similar topographical conditions, as was the case reported in the state of Sonora (Verona-Trejo *et al.* 2012). It is known that the fox is vulnerable to predation in these sites (Cyper *et al.* 2013). The presence of the desert fox is likely occasional in the new record, as the slopes in the

Figure 1. First photographic records of *Vulpes macrotis* in APFFVC.

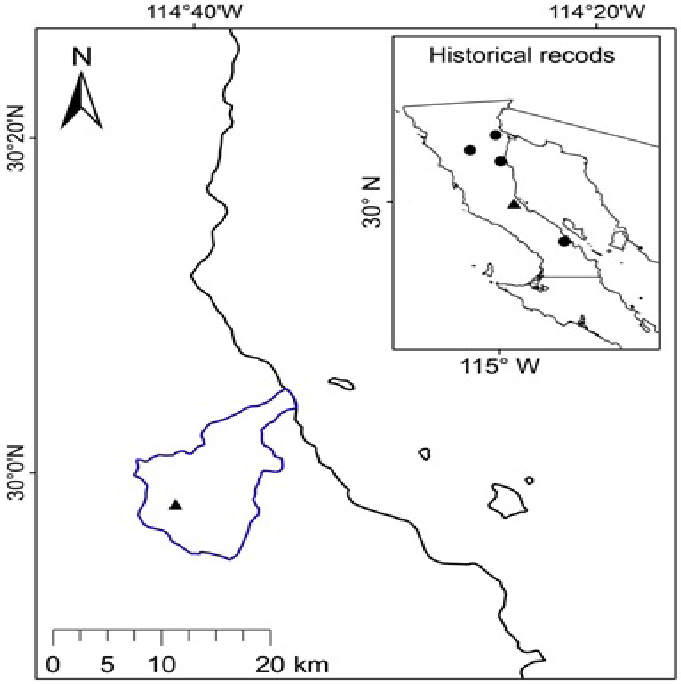

Figure 2. Record locality of *Vulpex macrotis*, in El Junco (black triangle), and historical record localities (black circles) in Baja California. The blue color represents Los Vascos basin.

area are greater than 10 degrees, and therefore not suitable for the construction of burrows (1998 Cyper and Spencer; List and Macdonald 2003; Harrison 2003; González-Bernal 2008). However, there are plains and sandy substrates less than 5 km to the east of El Junco, who have topographical features (roughness, slope and orientation) similar to those in the localities of historical records; hence, the presence of a resident population on the slopes that lead to the Gulf of California is likely, where the main preys of the kit fox *e. g.,* kangaroo rat (*Dipodomys simulans*), field rat (*Neotoma* sp.) and hare (*Lepus californicus;* White *et al.* 1996).

In a single night, the kit fox can travel distances between 10 and 15 km (Zoellick *et al.* 2002); therefore, it can travel daily across the whole Los Vascos basin, measuring 17.6 km long. Despite the absence of watering holes in the Gulf of California slopes, this carnivore is able to meet its water needs through the preys consumed daily, *i. e.*, 175 g of food, which represent approximately two rat specimens (*Neotoma* sp.; Golightly and Ohmart 1984; Olivas 2003).

The topography between the record localities of *V. macrotis* is similar, characterized by slopes inclination lower than 20°, roughness indicative of flat terrain, ideal for this species to escape from predators, and with a broad variety in slope orientations, a condition that favors the occupation of burrows (Cyper *et al.* 2013). A locality that apparently lacks suitable conditions for *V. macrotis,* is Valle de la Trinidad, which has an altitudinal gradient of 600 to 900 meters; however, riverbanks show slopes lower than 10° and are located at less than 15 km from the San Felipe desert. These conditions facilitate the displacement of the kit fox. The most isolated locality from all the historical records is Bahía Los Angeles, with the closest record located in El Vizcaíno Desert, 125 km to the southwest (Alvarez-Castañeda *et al.* 2008). In spite of this, Bahia Los Angeles is topographically similar in its streams and valleys that flow into the Gulf of California with La Venta, a locality that has the highest number of records of *V. macrotis* in Baja California. Despite no previous record of the kit fox existed in Sierra Santa Isabel, the analysis of topographic variables yielded similar characteristics to those of the localities of the historical records, and the presence of this species was confirmed through camera traps.

Table 1. Results of the topographic variables at each of the localities where *Vulpex macrotis* has been recorded in Baja California.

	Slope		**Roughness**		**Aspect**	
Locality	Mean	Stdev	Mean	Stdev	Mean	Stdev
El Junco	34.24	15.49	92.74	44.48	179.68	104.53
Ventana	13.46	12.50	22.29	25.67	117.78	106.76
San Felipe	31.60	13.79	59.52	24.67	179.42	107.88
V. Trinidad	18.56	12.09	45.90	37.61	178.14	96.01
B. Los Angeles	12.40	8.14	25.73	19.86	174.30	106.25

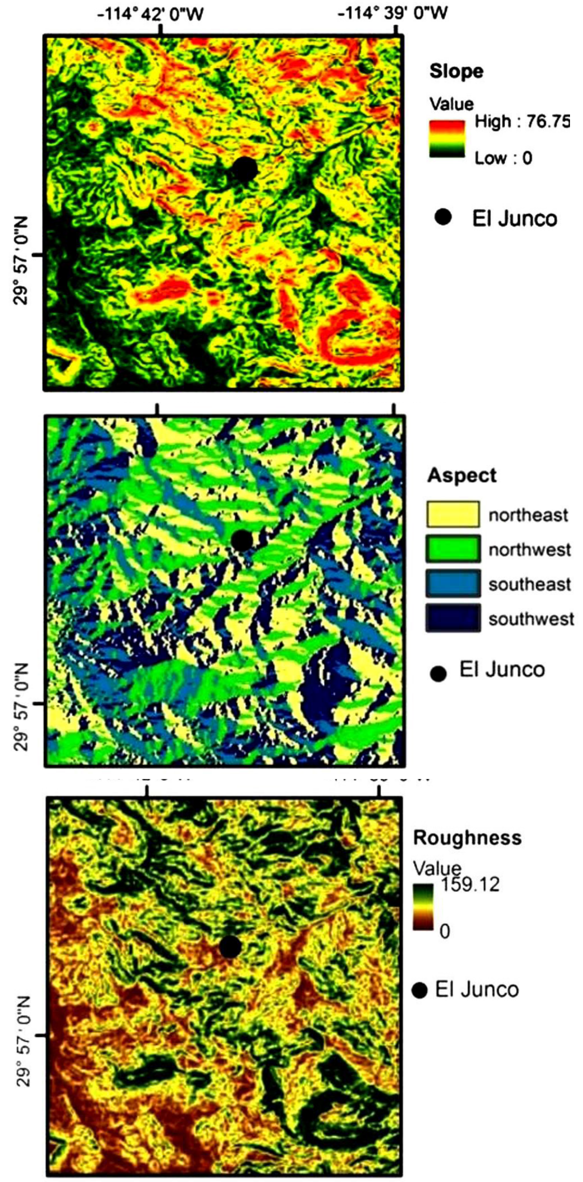

Figure 3. Digital terrain models that describe the topographical variables in El Junco, where *Vulpes macrotis* was recorded in APFFVC.

It is recommended to monitor the population of the *V. macrotis* at the mouth of the Los Vascos basin, as well as in streams and hills in Bahía Los Angeles. To determine the existence of resident populations who may be at risk by anthropogenic activities (roads and mining), which are currently on the rise in the region.

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Literature cited

Álvarez-Castañeda, S. T. 2000. Familia Canidae. Pp. 689–705, in Mamíferos del Noroeste Mexicano II. (Álvarez-Castañeda, S. T., and J. L. Patton, eds.). Centro de Investigaciones Biológicas del Noroeste, S. C. La Paz, México.

Álvarez-Castañeda, S. T., Rios, E., Cortés-Calva, P., González-Ruiz, N., and C. G. Suárez-Gracida. 2008. Mamíferos de las Reservas de El Valle de los Cirios y El Vizcaíno. Centro de Investigaciones Biológicas del Noroeste, S. C., Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. La Paz, México.

Álvarez-Castañeda, S. T., Alvarez T., and N. Gonzaléz-Ruiz. 2015. Guía para la identificación de los mamíferos de México en campo y laboratorio. Centro de Investigaciones Biológicas del Noroeste, S. C., Asociación Mexicana de Mastozoología A. C. Guadalajara, México.

Cyper, B. L., and K. A. Spencer. 1998. Competitive interactions between coyotes and San Joaquin kit fox. Journal of Mammalogy 79:204–14.

Cypher, B. L., S. E., Phillips, and P. A. Kelly. 2013. Quantity and distribution of suitable habitat for endangered San Joaquin kit foxes: conservation implications. Canid Biology and Conservation 16:25–31.

Golightly, R. T., and R. D. Ohmart. 1984. Water economy of two desert Canids: Coyote and Kit Fox. Journal of Mammalogy 65:51–58.

González-Abraham, C., Garcillán, P. P., and E. Ezcurra. 2010. Ecorregiones de la península de Baja California: Una síntesis. Boletín de la Sociedad Botánica de México 87:69–82.

González-Bernal, A. 2008. Distribución de la zorra del desierto *(Vulpes macrotis)* en relación a sus presas y a su principal depredador, el coyote *(Canis latrans)*. Tesis doctoral. Instituto de Ecología, A. C. Xalapa, México.

Harrison R., and J. Whitaker-Hoagland. 2003. A literature Review of Swift Fox Habitat and den-Site Selection. Pp. 79–89, in The swift fox: ecology and conservation in a changing world. (Sovada, M. A., and L. Carbyn, eds.). Canadian Plains Research Center. Regina, Canada.

Huey, L. M. 1964. The mammals of Baja California, México. Transactions of the San Diego. Society of Natural History 13:85–168.

List, R., and D. Macdonald. 2003. Home range and habitat use of the kit fox (*Vulpes macrotis*) in prairie dog (*Cyanomys ludovicianus*) complex. Journal of Zoology 259:1–5.

Olivas, M. M. 2003. Peso de neonatos de rata magueyera (*Neotoma albigula leucodon*), en cautiverio, del nacimiento a los 40 días de edad, en México. Agrociencia 37:231–235.

Plan de Manejo Valle de los Cirios. 2013. Programa de Manejo del Área de Protección Flora y Fauna Valle de los Cirios. Comisión Nacional de Áreas Naturales Protegidas. Guerrero Negro, México.

QGIS Development Team. 2016. QGIS Geographic Information System. Open source Geospatial Foundation. URL: http// qgis.osgeo.org

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria.URL: http://www.R-project.org/.

Roberts, N., and E. Ezcurra. 2012. Desert Climate. Pp. 1–23, in Baja California Plant Field Guide (Rebman, J. P., and N. C. Roberts, eds.). San Diego Natural History Museum. San Diego, U. S. A.

Riley, S. J., S. D. Degloria, and R. Elliot. 1999. A terrain ruggedness index that quantifies topographic heterogeneity. Intermountain Journal of Sciences 5:23-27.

Verona-Trejo, M. I., Bautista, R., and M. Martínez-Coronel. 2012. Registro de la zorra norteña (*Vulpes macrotis*) para el sur de Sonora. Therya 3:101–104.

Warrick, G. D., and B. L. Cyper. 1998. Factors affecting the spatial distribution of a kit foxes. Journal of Wildlife Management 62:707-717.

White, P. J., Vanderbilt-White, C. A., and K. Ralls. 1996. Function and numerical responses of kit foxes to a short-ter, decline in mammalian prey. Journal of Mammalogy 77:370-376.

Zoellick, B. W., Harris, C. E., Kelly, B. T., O´Farell, T. P., Kato, T. T., and M. E. Koopman. 2002. Movements and home range of San Joaquin kit foxes relative to oil-field development. Western North American Naturalist 62:151–159.

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Comparative efficiency of photographs and videos for individual identification of the Andean bear (*Tremarctos ornatus*) in camera trapping

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Identification of Andean bear (*Tremarctos ornatus*) specimens is essential for obtaining demographic estimates of their populations. Camera traps are a noninvasive tool that allows such identification. The efficiency of using photographic or video records for identifying specimens of this species in a wild population in Colombia was compared. A total of 18 camera traps were operated from November 2011 through November 2013; each sample station included a single camera at 0.6 m height, with a bait placed 2 m in front of it at 1.5 m height. Four key external morphological features were chosen for identifying the specimens: Presence, shape and colour of facial; presence, shape and colour of pectoral markings; estimated body size; and sex. For each recording event, a visual file (photograph or video) was scored as ¨good¨ if it showed at least three key identification features, thus allowing the correct identification of the specimen; or as ¨bad¨ if it showed fewer than three features, making identification impossible. Successful recording events were those that included at least one good visual file (photograph or video). A total of 4,588 visual files were obtained: 4,324 photographs in 325 recording events and 264 videos in 260 recording events. 5.25 % of the photographs and 53.03 % of the videos were scored as good files. 26.77 % of the photograph-based and 49.62 % of the video-based recording events were successful. There were statistically significant differences between the percentage of good photographs and good videos obtained every time a camera trap was activated in the presence of a bear (Mann-Whitney, *P* = 0.0001). The low percentage of successful recording events obtained with photographs (26.77 %) compared to that obtained with videos (50.38 %), is consistent with results previously reported for this same species in Ecuador using photographs (25.00 %). The higher percentage of good videos (53.03 %) compared to that of good photographs (5.25 %), is consistent with the statistically significant difference found between the percentage of good photos and good videos obtained every time a camera trap was activated in the presence of a bear (Mann-Whitney, *P* = 0.0001), and with results previously reported for the Asian black bear (*Ursus thibetanus*, 70.00 %) using sample stations including a single camera trap with video format. The use of video for recording Andean bear specimens allows the observation of individuals from different viewpoints and distances, even with the use of sample stations including a single camera trap, thus minimizing the effect of light reflection on the recognition of key identification features. Additionally, the video format allowed recognition of particular physical conditions, such as limp or rigid limbs in some specimens, which cannot be recognized in photographs. In this study case, information obtained with video records provides a greater ability to recognize individual marks in the specimens and to identify them.

La identificación de ejemplares de oso andino (*Tremarctos ornatus*) es indispensable para la realización de cálculos demográficos de sus poblaciones, y las cámaras trampa son una herramienta no invasiva que permite dicha identificación. Se examinaron comparativamente la efectividad del uso de fotos y videos en la identificación de ejemplares de esta especie en una población silvestre en Colombia. Se instalaron 18 cámaras trampa (noviembre 2011 - noviembre 2013), en estaciones de una sola cámara a 0.6 m de altura, con un cebo a 2 m de distancia y 1.5 m de altura. Se escogieron cuatro características morfológicas externas clave para la identificación de los individuos: presencia, forma y color de las manchas faciales; presencia, forma y color de las manchas pectorales; tamaño estimable; sexo. En cada evento de registro, se calificó como archivo visual (foto o video) bueno aquel que mostró ≥ 3 características clave que permitieron la identificación, y como archivo malo aquel que mostró < 3 características, en el cual no fue posible dicha identificación. Eventos de registro (de fotos o videos) exitosos fueron aquellos que contuvieron al menos un archivo visual bueno. Se obtuvieron 4,588 archivos visuales: 4,324 fotos en 325 eventos de registro y 264 videos en 260 eventos de registro. Para el formato de foto, 5.25 % fueron fotos buenas y 94.75 % malas. Para el formato de video, 53.03 % fueron videos buenos y 46.97 % malos. Para el formato de foto, 26.77 % eventos de registro fueron exitosos. Para el formato de video, 49.62 % eventos de registro fueron exitosos. Existió diferencia estadística entre el porcentaje de fotos buenas y videos buenos obtenidos cada vez que una cámara trampa se activó ante la presencia de un oso (Mann-Whitney, *P* = 0.0001). El bajo porcentaje de eventos de registro exitosos con el formato de foto (26.77 %) respecto al de video (50.38 %), concuerda con lo reportado previamente para esta especie en Ecuador mediante el uso de fotos (25.00 %). El alto porcentaje de videos buenos (53.03 %) respecto al de fotos buenas (5.25 %), es soportado por la diferencia estadística entre el porcentaje de fotos buenas y videos buenos obtenidos cada vez que una cámara trampa se activó ante la presencia de un oso (Mann-Whitney, *P* = 0.0001), y concuerda con lo reportado previamente para el oso negro asiático (*Ursus thibetanus;* 70.00 %) en estaciones de una cámara en formato de video. El registro de ejemplares con el formato de video permite la observación del individuo desde diferentes posiciones y distancias, incluso con el uso de una sola cámara trampa por estación, minimizando el efecto del reflejo de la luz sobre el reconocimiento de características clave para la identificación. Adicionalmente, el formato de video permitió reconocer condiciones físicas particulares como cojeo o extremidades rígidas en algunos individuos, aspectos no reconocibles mediante fotografías. En el caso de estudio, la información obtenida con el formato de video sugiere una mayor capacidad para el reconocimiento de marcas individuales de los ejemplares y su identificación.

Key words: Andean bear; camera trapping; Colombian Andes; specimen identification.

Introduction

Andean bears (*Tremarctos ornatus*) are large carnivores (1.5 - 2.1 m total length; 70 - 130 kg body weight), that inhabit paramo, puna and Andean forests between 250 and 4,750 m along the Andes mountain range (Peyton 1999). This species ranges from Colombia through Ecuador, Peru and Bolivia (Peyton 1980, Rodríguez *et al.* 2003), to northern Argentina (Del Moral and Bracho 2009). The mountainous habitat that this species inhabits makes the study of its natural history difficult (Jones 2010).

A number of research studies on the Andean bear have been conducted throughout its distribution range (García-Rangel 2012, Reyes-Amaya 2015). However, key aspects of their natural history such as population dynamics, habitat use and ethology in the wilderness (*e. g.*, courtship and reproduction) have been scarcely described (Reyes-Amaya 2015). The large area requirements (home range: 59 km^2 for males, 15 km^2 for females) and heterogeneity of the Andean bear habitat, along with their vulnerability to land use by humans and prolonged parental care, all increase the extinction risk for this species (Stern 1998; Cardillo *et al.* 2004; Castellanos 2011). Therefore, it is crucial to gain a better understanding of the Andean bear biology for formulating and implementing suitable strategies for their conservation and management (Rodríguez *et al.* 2003).

Mammalian identification based on natural marks of the specimens (*e. g.*, external coloration patterns) has been extensively used to estimate population patterns from trap camera images (Foster and Harmsen 2012). The Andean bear coat varies from black to dark brown, usually with white markings or other colour variants on the snout, neck, chest and around the eyes (although some individuals do not show any markings), which show distinct variations between specimens (Roth 1964; Peyton 1999). Previous studies have used camera traps to address population aspects of the Andean bear (*e. g.*, catch rates, population density, abundance) and some of those have evaluated the effectiveness of this technique for identifying specimens of this species (Ríos-Uzeda *et al.* 2007; Zug 2009; Van Horn *et al.* 2014). However, due to the recent implementation of video format in camera traps, no information is yet available on the comparative efficiency of using either photographs or videos in camera traps for identifying Andean bear specimens. In this study we examine photographic and video records of Andean bears acquired by camera traps in a wild population to compare the efficiency of the two visual file formats for identifying individuals.

Materials and methods

The study area includes parts of the Gachetá and Junín municipalities in the Cundinamarca Department. These municipalities are located on the western slope of the eastern cordillera of the Colombian Andes, under the jurisdiction of the Corporación autónoma Regional del Guavio (CORPOGUAVIO), the State environmental authority in this part of the country. The mountainous topography of the study area comprises moderate to steep slopes (undulating to rugged terrain) in colluvial landscapes and denudative structural mountains, covered by fragmented Andean forest, sub-paramo and paramo ecosystems, between 2,500 and 3,200 m (Cleef 1978). Mean annual temperatures range between 5.7 and 16 ° C (Rangel-Ch 2000; Vargas and Pedraza 2004), with mean annual precipitation of up to 1,861 mm and humidity up to 90 %, in a unimodal seasonal rainfall regime; the rainy season runs from April to October (with a peak in June and July) and the dry season from November through March (minimum rainfall between December and January; INDERENA 1986, Aguilar and Rangel-Ch 1996).

Natural trails made by Andean bears within the forest were located based on traces of habitat use by this species (*e. g.*, evidence of climbing and presence of camaretas on trees, feeders and feces) and the knowledge of community research monitors (local residents). We selected those trails showing the most signs of recent use by the species (≤ 6 months, see Rodríguez 2006), in order to obtain the largest possible number of visual records. Trap cameras were located at sampling stations along the trails within the forest (Zug 2009; Jones 2010). Each sampling station included a single camera attached to a tree trunk at 0.6 m height, with the bait (honey or panela) placed 2 m from it at 1.5 m height, to encourage the specimens to raise on their hind limbs to reach the bait.

A total of 18 camera traps of different brands and models, but with similar photographic qualities or the same video quality, were used (Table 1). The cameras were active for two years (November 2011 to November 2013), programmed to operate 24 hours a day, taking a sequence of photographs or videos every time they were activated by motion in front of them (recording event). Visual files in which an Andean bear was not recorded were excluded from further analysis. Photograph sequences were taken with 1 second interval between shots for as long as the subject was in front of the camera. For video recordings, 60-second videos were shot with 1 second interval between them for as long as the subject was in front of the camera. The cameras were checked every 15 days to verify their proper functioning, download the visual files acquired and replace batteries. Visual files acquired were tagged with the recording date and time.

For each recording event, an attempt was made to identify the specimen within each visual file acquired. Specimens were identified based on the presence of four key external morphological features (attributes useful for specimen identification): presence, shape and colour of facial markings; presence, shape and colour of pectoral markings; estimated body size; and sex, as observed from three different viewpoints, as described by Zug (2009) (Figure 1). The body size of the specimen was estimated by comparison with a reference object of known size located within the visual field of the camera; sex was determined either based on the specimen's genitalia (when visible) or the presence of other reproductive features (*e. g.*, turgid mammary glands, presence of

Table 1. Brands, models and quality of photographs and videos acquired by camera traps used in the study. Photograph quality is measured in megapixels (Mp), video quality is measured in pixels (p). Bushnell Trophy Cam ™ HD HD 119476 (Bushnell), Reconyx Hyper Fire Infrared Digital Game Camera HC600 (Reconyx), Wildview® SCT-TGL5IR (Wildview).

			Number		
Camera trap	**Photograph quality**	**Video quality**	**Photographs**	**Videos**	**Total**
Bushnell	5.0 Mp	1,280 x 720 p	4	8	12
Reconyx	3.1 Mp	-	2	0	2
Wildview	5.0 Mp	-	4	0	4

cubs). A visual file (photograph or video) was scored as "good" for identification of the specimen when at least three of the four key features could be clearly observed in it. A visual file was scored "bad" when only two or fewer identification features could be observed. Facial and pectoral markings are perhaps the most useful features for identifying specimens of this species (Roth 1964; Peyton 1999). However, not all the specimens show both kinds of markings, in which case the identification must be complemented withother features (e.g., estimated body size and sex). The use of complementary features allows discriminating between specimens even with basis on one single marking, which might appear rather similar in different specimens as it is not always possible to fully observe the entire marking in visual files (photograph or video). Additionally, some bear specimens do not display any marking, which makes their identification impossible (D. Rodríguez com. Pers.).

The percentage of recording events that included good visual files, and thus allowed the correct identification of the specimen recorded (successful recording events), as well as the percentage of recording events that did not include any good visual files, and thus made the specimen identification impossible (unsuccessful recording events), were separately calculated for each photograph/video data set acquired during the entire sampling period (Table 2). Similarly, the percentage of good and bad visual files acquired over the entire sampling period was separately calculated for each photograph/video data set (Table 2).

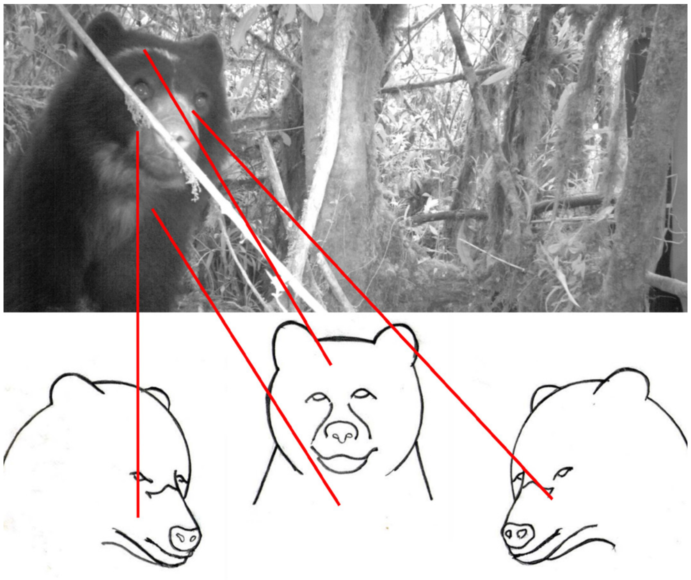

Figure 1. Scheme showing how facial features were recorded for the identification of Andean bear specimens using camera traps.

In addition, by considering each recording event as an independent event, we tested for statistically significant differences in the number of good and bad visual files acquired every time a camera was activated by the motion of an Andean bear in front of it. Comparisons were made within the photograph and video data sets and between the two sets. As the number of visual files acquired in each recording event was variable, prior to analysis the number of good and bad visual files was expressed as a percentage of the total number of files acquired in the recording event. As the data showed a non-normal distribution, the non-parametric Mann-Whitney test was used for the analyses.

Results

A total of 585 recording events were obtained, comprising a total of 4,588 visual files (4,324 photographs in 325 recording events and 264 videos in 260 recording events, Table 2). Of the 325 recording events that used photographs, 26.77 % (87) were successful, allowing the identification of the specimen recorded; 49.62 % (129) of the recording events that used videos were successful (Table 2).

Of the total number (4,324) of photographs acquired, 5.25 % (227) were rated as good and 94.75 % (4,097) as bad (Table 2). There was a statistically significant difference in the percentage of (good) photographs that allowed the specimen identification when the camera trap was activated by the motion of an Andean bear in front of it and those (bad) photographs that did not (Mann-Whitney, *P* = 0.0001). Of all the videos acquired (264), 53.03 % (140) were rated as good and 46.97 % (124) as bad (Table 2). There was a statistically significant difference in the percentage of (good) videos that allowed the specimen identification when the camera trap was activated by the motion of an Andean bear in front of it and those (bad) videos that did not (Mann-Whitney, *P* = 0.0001). The combination of identification features that most frequently appeared in good photographs was facial marking-estimated body size-sex (in 51.98 % of these photographs); estimated body size (without other accompanying characteristics) was the identification feature that most frequently appeared in bad photographs (in 79.13 % of these photographs). Facial marking-pectoral marking-estimated body size-sex was the features combination that most frequently appeared in good videos (in 69.29 % of these); pectoral marking-sex was the combination appearing most frequently in bad videos (in 49.19 % of these).

Comparison of the results obtained with the two visual formats (photograph and video) showed a statistically significant difference between the percentage of good photographs and good videos acquired every time the camera trap was activated by the motion of an Andean bear in front of it (Mann-Whitney, $P = 0.0001$), as well as between the percentage of bad photographs and bad videos (Mann-Whitney, $P = 0.0001$).

Discussion

Results from this study showed (Table 2) that the visual file format chosen for recording affects the ability to identify specimens of Andean bear in camera trap work. The video format provided a better capacity to identify specimens, with a higher percentage (49.62 %) of successful recording events that resulted in the correct identification of the specimen, compared to that obtained from cameras set in photograph mode (26.77 %; Table 2). These results are in agreement with those reported by Zug (2009) (25 % successful recording events, out of 28) in Ecuador using photographs, but differ from those obtained by Ríos-Uzeda *et al.* (2007) (42.86 % successful recording events, out of 7) in Bolivia with the same visual file format. This difference may be due to the small number of recording events acquired by Ríos-Uzeda *et al.* (2007), which prevented recognizing a clear pattern in the effectiveness of photographs for identifying Andean bears.

In our study, the higher percentage of video recordings that allowed the correct identification of Andean bear specimens (53.03 % good videos), compared to that obtained with photographs (5.25 % good photos; Table 2), is supported by the statistically significant difference (Mann-Whitney, $P = 0.0001$) found between the percentage of photographs and videos that allowed the correct identification of the specimen (good visual files) every time a camera was activated by the motion of an Andean bear in front of it. These results are in agreement with those reported by Higashide *et al.* (2013) for the Asian black bear (*Ursus thibetanus*) in Japan, where the percentage of videos that allowed the specimen identification was up to 70.00 % in sampling stations including single-camera traps.

Facial and pectoral markings are considered as the key distinctive features of Andean bear specimens (Roth 1964; Peyton 1999). In our study, the combinations of identifying features most frequently observed in photographs (facial marking-estimated body size-sex) and videos (facial marking-pectoral marking-estimated body size-sex) that successfully allowed the specimen identification (good visual files), compared with those observed in photographs (estimated body size without other accompanying characteristics) and videos (pectoral spot-sex) that did not (bad visual files), showed the greater capacity of the video format to clearly record the body markings of Andean bears. Studies on this species using photograph camera traps recommend using sampling stations supplied with 2 to 3 camera traps to acquire images of the specimens from different viewpoints in which body markings can be more clearly observed (Ríos-Uzeda *et al.* 2007; Zug 2009). However, in our study on Andean bear, as well as in that by Higashide *et al.* (2013) on Asian black bear, single video camera traps were used per season, combined with the use of attractant baits placed in front of the camera at a height that prompted the specimen to raise on its hind legs to reach the bait. The use of this sampling station configuration made it possible observing the features necessary to correctly identify Andean bear specimens using a single camera trap set on video format, obtaining a greater number of successful recording events (49.62 %; Table 2) compared to those obtained with two- (Ríos-Uzeda *et al.* 2007; 42.86 %) or three- (Zug 2009; 25.00 %) camera sampling stations using photograph format.

Observing the Andean bear's body markings can be made difficult by illumination conditions under the forest canopy, which cause reflections that make observation of the markings shape and color difficult. The video recording of the specimens allows this negative effect to be ameliorated, as variations of light reflection on the markings can be tracked as the video progresses and the specimen changes its position in front of the camera. In most of the recording events acquired in this study the specimens recorded sought the bait by standing on their hind legs to reach it and approached the camera trap to inspect it closely. This allowed observing the specimens in different positions and distances from the camera, providing sufficient information on the presence, shape and color of facial and pectoral markings and of other key features such as the specimen's body size and sex, as well as of additional reproductive characteristics such as the presence of turgid mammary glands or cubs accompanying postpartum females. However, some specimens do not show any body markings and cannot, therefore, be identified (D. Rodríguez com. Pers.), regardless of the visual file format used. This study presents the first formal report of this condition in Andean bears.

In the course of this study two bears bearing particular physical conditions related to restricted mobility of their hind limbs (limping and rigidity of one of the limbs) were video recorded. This would allow the identification of these

Table 2. Visual files and recording events acquired in the study, their quality and capacity to allow identification of Andean bear specimens. Number of files (NF), total number of files (TF), total number of recording events (TRE), number of successful events (SRE), and number of non-successful events (NSRE)

	Good		Bad					
Format	**NF**	**%**	**NF**	**%**	**TF**	**TRE**	**SRE**	**NSRE**
Photographs	227	5.25	4,097	94.75	4,324	325	87 (26.77 %)	238 (73.23 %)
Videos	140	53.03	124	46.97	264	260	131 (50.38 %)	129 (49.62 %)

particular specimens, and could not have been possible with the use of photographs.

The use of camera traps has proved to be very useful in the study of Andean bear populations (Ríos-Uzeda *et al.* 2007; Zug 2009). However, the proper application of population models depends in part on having an adequate individualization of the specimens recorded. This fact highlights the importance of having a good knowledge of the relative efficiency of the different data formats that can be acquired with camera traps (photographs or videos) for identifying specimens, as a key aspect for the inclusion of these records in population studies (Foster and Harmsen 2012). The use of camera traps using video format is recommended.

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Literature cited

Aguilar, M., and J. O., Rangel-Ch. 1996. Clima de alta montaña en Colombia. Pp. 73-130 in El páramo: ecosistema a proteger. Serie Montañas Tropoandinas II (Aguilar, M., and J. O. Rangel-Ch, eds.). Fundación de Ecosistemas Andinos (ECOA). Bogotá, Colombia.

Cardillo, M., A. Purvis, W. Sechrest, J. L. Gittleman, J. Bielby, and G. M. Mace. 2004. Human population density and extinction risk in the world's carnivores. PLoS Biology 2:909-914.

Castellanos, A. 2011. Andean bear home ranges in the Intag region, Ecuador. Ursus 22:65-73.

Cleef, A. M. 1978. Characteristics of neotropical paramo vegetation and its subantarctic relations. Pp. 365-390, in Geoecological relations between the southern temperate zone and the tropical mountains (Troll, C., and W. Lauer, eds.). Erdwiss Forsch. Wiesbaden, Germany.

Del Moral, F., and E. Bracho. 2009. Indicios indirectos de la presencia del oso andino (*Tremarctos ornatus*, Cuvier, 1825) en el noroeste de Argentina. Revista Museo Argentino de Ciencias Naturales 11:69-76.

Foster, R. J., and B. J. Harmsen. 2012. A critique of density estimation from camera-trap data. Journal of Wildlife Management 76:224-236.

García-Rangel, S. 2012. Andean bear *Tremarctos ornatus* natural history and conservation. Mammal Review 42:85-119.

Higashide, D., S. Miura, and H. Miguchi. 2013. Evaluation of Camera-Trap Designs for Photographing Chest Marks of the Free-Ranging Asiatic Black Bear, *Ursus thibetanus*. Mammal Study 38:35-39.

Instituto Nacional de los Recursos Naturales Renovables (Inderena). 1986. Parques Nacionales, Instituto Nacional de Recursos Naturales, Fondo FEN. Bogotá, Colombia.

Jones, T. 2010. Detection probability and individual identification of the Andean Bear (*Tremarctos ornatus*) using camera trapping methods. Master Thesis, University of Wisconsin. Madison, U. S. A.

Peyton, B. 1980. Ecology, distribution, and food habits of spectacled bears, *Tremarctos ornatus* in Peru. Journal of Mammalogy 61:639-52.

Peyton, B. 1999. Spectacled bear conservation action plan. Pp. 157-198, in Bears, status survey and conservation action plan (Servheen, C. S., S. Herrero, and B. Peyton, eds.). IUCN/SSC Bear and polar bear specialist group. Gland, Switzerland.

Rangel-Ch, J. O. 2000. Clima de la región paramuna. Pp. 85-125 in La región de vida paramuna. Colombia diversidad Biótica III (Rangel-Ch, J. O, ed.). Universidad Nacional de Colombia, Facultad de Ciencias, Instituto de Ciencias Naturales. Bogotá, Colombia.

Reyes-Amaya, N. 2015. Familia Ursidae. Pp. 166-171 in Los carnívoros terrestres y semiacuáticos continentales de Colombia (Suárez-Castro, A. F., and H. E. Ramírez-Cháves, eds.). Universidad Nacional de Colombia. Bogotá, Colombia.

Ríos-Uzeda, B., H. Gomez, and R. B. Wallace. 2007. A preliminary density estimate for Andean bear using camera-trapping methods. Ursus 18:124-128.

Rodríguez, D., F. Cuesta, I. Goldstein, L. Naranjo, and O. Hernández. 2003. Estrategia ecorregional para la conservación del oso andino *Tremarctos ornatus* en los Andes del norte. WWF, Fundación Wii, Ecociencia, Wildlife Conservation Society. Bogotá, Colombia.

Rodríguez, D. 2006. Manual de identificación de rastros y huellas de oso andino en los páramos y bosques andinos en Colombia. Fundación para la Investigación, Conservación y Protección del Oso Andino (Wii). Bogotá, Colombia.

Roth, H. 1964. Ein Beitrag zur Kenntis von *Tremarctos ornatus* (Cuvier) Der. Zoologische Garten 29:107-129.

Stern, S. J. 1998. Field studies of large mobile organisms: scale, movement and habitat utilization. Pp. 289-307, in Ecological scale: theory and applications (Peterson, D. L., and V. T. Parker, eds.). Columbia University Press. New York, U. S. A.

Vargas, O., and P. Pedraza. 2004. Parque Nacional Natural Chingaza. Departamento de Biología, Universidad Nacional de Colombia. Bogotá, Colombia.

Van Horn, R. C., B. Zug, C. Lacombe, X. Velez-Liendo, and S. Paisley. 2014. Human visual identification of individual Andean bears *Tremarctos ornatus*. Wildlife Biology 20:291-299.

Zug, B. 2009. Individual identification and habitat use of Andean bears on private lands in the Ecuadorian Andes. Master Thesis. University of Wisconsin. Madison, U. S. A.

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