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ECOLOGÍA

The use of camera traps to study the hooded skunk *Mephitis macroura* (Carnivora: Mephitidae) abundance

Uso de trampas cámara para el estudio de la abundancia del zorrillo rayado sureño *Mephitis macroura* (Carnivora: Mephitidae)

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ABSTRACT

Skunks are important for the ecosystems as consumers of fruits, seeds, and insects. The hooded skunk (*Mephitis macroura*) is a medium-sized mammal common in North America, but its abundance is poorly known throughout its range. In a semiarid location in southern Mexico, we deployed a camera traps array to study the populations of meso-carnivores in three seasons. With 2520 camera days of sampling effort, we obtained 41 photographs of the hooded skunk, an average of 6.2 photographs per station, meaning a capture rate of 1.63 photographs/camera-day per 100. Based on pelage color patterns and specific characteristics, we identified 25 individuals (seven to twelve skunks per season). Single camera-trap stations recorded up to seven different skunk individuals (an average of 3.6 individuals). The maximum number of capture-recaptures was four for three skunk individuals, and the average capture-recapture record was 1.4 per skunk. Although the survey area was appropriate for mesocarnivores, no spatial recaptures were observed for hooded skunks because the distance between cameras was longer. Traditional capture-recapture models estimated hooded skunk abundance at 12.60, 21.10, and 20.20 skunks during the dry, pre-rainy, and rainy seasons, respectively. The capture rate was higher than reported in other camera trapping surveys in Mexico, and estimated abundances were the lowest but, in the range, reported for the species using other techniques. Idiosyncratic characteristics of hooded skunks are useful to the recognition of individuals, but we recommend testing short distances among cameras to achieve spatial recaptures and to apply contemporary spatial capture-recapture analyses.

Keywords: dry forest, intraspecific tolerance, mesocarnivores, Mixteca region, population abundance.

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RESUMEN

Los zorrillos son importantes para los ecosistemas como consumidores de frutas, semillas e insectos. El zorrillo rayado sureño (*Mephitis macroura*) es un mamífero de tamaño mediano común en Norteamérica, pero su abundancia es poco conocida en su distribución. En un lugar semiárido del sur de México, colocamos cámaras-trampa para estudiar las poblaciones de mesocarnívoros en tres temporadas. Con 2520 días-cámara de esfuerzo de muestreo, obtuvimos 41 fotografías del zorrillo rayado sureño, en promedio 6,2 fotografías por estación, igual a una tasa de captura de 1.63 fotografías/día-cámara por 100. Los patrones de color del pelaje y características específicas permitieron identificar 25 individuos (siete-doce zorrillos/temporada). Las estaciones de cámaras-trampa individuales registraron hasta siete individuos diferentes de zorrillos (promedio 3,6) y el número máximo de capturas-recapturas fue de cuatro para tres individuos de zorrillo (promedio 1,4). Aunque el área de estudio fue apropiada para mesocarnívoros, no se observaron recapturas espaciales de zorrillo rayado sureño porque la distancia entre las cámaras fue amplia. Los modelos tradicionales de captura-recaptura estimaron la abundancia del zorrillo rayado sureño en 12,60; 21,10 y 20,20 durante las estaciones seca, pre-lluviosa y lluviosa. La tasa de captura fue más alta comparada con otros estudios con cámaras-trampa en México, pero las abundancias estimadas fueron las más bajas, pero dentro del intervalo reportado para la especie usando otras técnicas. Las características idiosincrásicas del zorrillo rayado sureño son útiles para el reconocimiento de individuos. Recomendamos probar distancias cortas entre cámaras-trampa para lograr recapturas espaciales y aplicar análisis contemporáneos de captura-recaptura espaciales.

Palabras clave: abundancia poblacional, mesocarnívoro, región Mixteca, selva seca, tolerancia intraespecífica.

INTRODUCTION

Species´ population sizes are dynamic and influenced by intrinsic factors to species, environmental conditions, interspecific interactions (Seitz and Loeschcke 1991, Lande 1993), and human causes (Ceballos *et al.* 2010). Information on species population abundance is of concern not only to ecological sciences but also to management and conservation (Bessinger and Westphal 1998, Loh *et al.* 2005, Mills 2012, Fryxell *et al.* 2014).

The hooded skunk, *Mephitis macroura* Lichtenstein, 1832 is a usually solitary medium-sized mammal, that feeds mainly on fruits and insects (Hwang and Larivière 2001, Hass 2003); it is common across its distribution range, from the southern United States of America throughout Mexico to northern Costa Rica (Hwang and Larivière 2001). The hooded skunk inhabits lowlands arid scrub, deciduous and coniferous forests, and riparian areas, from sea level to 3000 m. Also, the species tolerates human-modified habitats as well (Mora 2000, Hwang and Larivière 2001, Pacheco 2005). Despite the ordinariness of the hooded skunk, populational studies across its range are scarce, and those available showed an estimated density ranging from 0.46 to 3.9 individuals/km^2, throughout transects and captures in traps (List and MacDonald 1998, Cervantes *et al.* 2002, Hass 2003, Lorenzo *et al.* 2005).

It has been noted that the hooded skunk shows a wide variety of pelage coloration (Hass 2003). Variations include black individuals, or with one or two stretch lateral lines whitish to individuals with the back and tail entirely whitish (Patton 1974, Hoffmeister 1986, Aranda 2000, Hwang and Larivière 2001, Pacheco 2005, Álvarez-Castañeda *et al.* 2017). Even, in the same litter, the pups have different color patterns (Janzen and Hallwachs 1982). To date, such traits have not been used in population studies as in other less common species (Burton *et al.* 2015, Mandujano 2019). In this study, we take advantage of the individual variation in the coloration pelage pattern of the hooded skunk to identify individuals photographed with camera traps and determine the variation of abundance through the seasons. Due to the dry season had higher food availability (Otero-Arnaiz *et al.* 2003, Ortíz *et al.* 2010, Cruz

and Pavón 2013, Herrera *et al.* 2013), and the arthropods biomass increase in this season (Serrano-Cardozo *et al.* 2008), we expected higher capture rate and abundance of the hooded skunk than in the rainy and pre-rainy seasons.

MATERIALS AND METHODS

Study site

The study took place in the Municipality of Cosoltepec, located in the Mixteca region, state of Oaxaca, southern Mexico (18°8' North and 97°47' Western; Fig. 1). The study site is characterized by hilly physiography with an elevational range from 1600-1800 m, and a semi-warm and semi-humid climate, with a rainy season in summer and drought in winter (INEGI c1998). The average annual precipitation is 800 mm and the annual average temperature is 18-22 °C (maximum 40 °C and minimum 4 °C; Guizar 2011, Cervantes and Riveros 2012). The heterogeneous landscape is composed of a matrix of grazing areas, seasonal crops, and patches of succulent scrub, deciduous forest, and secondary vegetation (INEGI c2015).

Camera-trap survey

In December 2013, we deployed fourteen camera traps (Cuddeback® models Capture and Expert, Green Bay, Wisconsin) in a grid disposition within a minimum polygon convex of 19.7 km² (Fig. 1). The distance between camera traps was 1.5 km approximately; this distance was based on the home range of the hooded skunk, estimated between 2.8-5.0 km in dry forests in western Mexico (Ceballos and Miranda 1986). Camera traps were set at 30 cm above the ground, tested, and programmed to work 24 h, with the minimum delay time among models (30 s for the Capture model and 60 s for the Expert model) with the purpose of obtaining many photographs and observe all the possible characteristics for everyone. We did not use any bait. Cameras took only photographs and were checked monthly to download images and change the batteries.

Data analysis

We classified the photographs by color pattern (Monroy-Gamboa *et al.* 2021) and by distinctive characteristics that allow us to identify individuals (e. g. unique strands by color or position, lines, and size of mots). Each subsequent photograph of an individual with identical characteristics was considered a recapture (Sarmento *et al.* 2009, Figueroa-de-León *et al.* 2017). With the cumulate of capture and recapture data, we calculated several measures of abundance, including capture rate, minimum number alive, and abundance. The capture rate was calculated as the number of photographic events divided by the number of camera traps working multiplied by 100 (Jenks *et al.* 2011). We calculated the minimum number of skunks alive with the accumulated number of individuals. The abundance was estimated with capture-recapture models in the SECR package (Efford c2019) development for the R environment (R Development Core Team c2012). In SECR, we probed several models: *Mo*, or null model, assumes the same probability of capture between individuals; the *Mh*, or heterogeneity model, assumes that detection probability varies between individuals; and *Mt*, assumes that detection probability varies with the time. The best-fitted model was selected using Akaike´s Information Criterion corrected for small sample sizes (*AICc*). For the calculus, we used ten days as a trapping occasion to reach a model convergence. We fit a test of closure population with the *Z* value statistic and *P* value for the Otis *et al.* (1978) test.

Measures of abundance were analyzed in three 60-day survey periods: 1) dry season, 22 December 2013-19 February 2014; 2) pre-rainy season, 20 February-19 April 2014; and 3) rainy season, 20 April June 2014. The survey periods were classified based on precipitation and temperature data obtained from the nearest meteorological station (Tehuacán, Puebla, 50 km N; https://es.climate-data.org/america-del-norte/mexico/puebla/tehuacan-4626/). The 60-day survey periods were used to assume the composition of the population during the survey did not change.

RESULTS

With 2520 camera days of sampling effort, in the three survey seasons grouped, we obtained 41 photographs of the hooded skunk and identified 25 individuals. The capture rate was higher in the pre-rainy season than in the dry or rainy seasons (Table 1). Only one photograph could not be associated with any individual (Monroy-Gamboa *et al.* 2021) because the individual was photographed from the back and thus was excluded from the abundance analyses.

Skunks were photographed in seven of the fourteen camera-trap stations, with an average of 6.2 photographs per station (two to ten photographs). Single camera-trap stations recorded up to seven different skunk individuals with an average of 3.6 individuals. In the dry season,

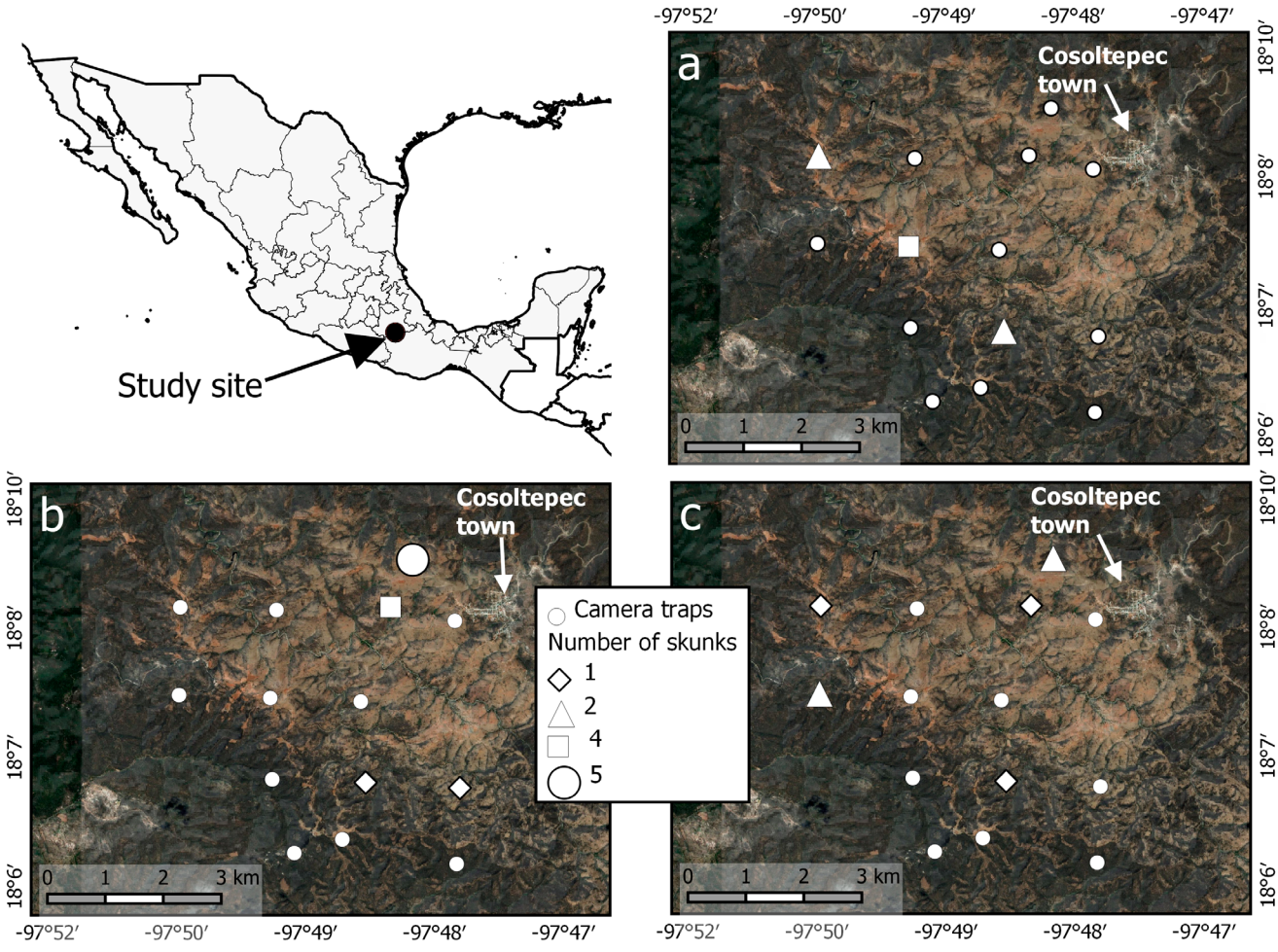

Figure 1. Localization of camera trap-stations for the hooded skunk study in the Mixteca region, Mexico. Circles depict number of different individuals in season surveys. **a**. dry season, **b**. pre-rainy season, and **c**. rainy season.

camera-trap stations recorded up to four individuals. In the pre-rainy, one camera-trap station recorded five individuals, and another recorded four. And in the rainy season, the maximum number of skunks recorded by any camera-trap station was three. The maximum number of capture-recaptures was four for three skunk individuals: one in the dry season and two for the pre-rainy season; the average of capture-recaptures was 1.4 per skunk. All individuals were recorded in only one camera-trap station, i.e., there were no spatial recaptures (Table 1).

The minimum number of "alive" skunks varied per season, with a mean of nine individuals (Table 2). The highest number of individuals identified was in the pre-rainy season (twelve individuals), followed by the dry season (eight individuals), and finally, in the rainy season (seven individuals). In total, we identified 25 individuals; most of them were observed only in one season, whereas only one individual was observed in two seasons (pre-rainy and rainy seasons) (Table 2).

Abundance. The null models perform better than the heterogeneity models for the three seasons. According to model selection, the best-fitted model (smallest AICc value) was used to estimate the parameters. The estimated abundance was between 12.60 and 21.10 individuals (mean 17.00; Table 2).

DISCUSSION

Despite skunk's environmental, cultural, and enzootic importance, populational studies have seldom rarely to this mammal group (Burton *et al.* 2015, Mandujano 2019). The method applied, identification of individuals by pel-

age color pattern and idiosyncratic characteristics had been widely used for abundance estimates in a limited number of species using camera trapping, for example, tigers (Karanth et al. 2017, Harihar et al. 2018) and jaguars (Maffei et al. 2011). However, there are fewer studies with medium-sized species. There are examples of studies with red foxes (Vulpes vulpes Linnaeus, 1778) in Portugal (Sarmento et al. 2009) and pacas (Cuniculus paca Linnaeus, 1766) in southern Mexico (Figueroa-de-León et al. 2017). Although these studies, including the present, show the utility of physical characteristics of pelage in applying camera trapping, other methods should be evaluated for comparisons or to complement.

Table 1. Distribution spatial and number of captures of the hooded skunk (*Mephitis macroura*) in the Mixteca region, Mexico.

Season/ Individual	Camera-trap station							
	A2	A3	A4	A10	A12	A13	A14	Total
Dry								
Ind 1						1		1
Ind 2						1		1
Ind 3						1		1
Ind 4							1	1
Ind 5	1							1
Ind 6						1		1
Ind 7							2	2
Ind 8	4							4
Pre-rainy								0
Ind 9	1							1
Ind 10					1			1
Ind 11			1					1
Ind 12			1					1
Ind 13					2			2
Ind 14			3					3
Ind 15			1					1
Ind 16					1			1
Ind 17					4			4
Ind 18				4				4
Ind 19			1					1
Rainy								0
Ind 14			1					1
Ind 20			1					1
Ind 21		1						1
Ind 22			1					1
Ind 23		1						1
Ind 24					1			1
Ind 25	2							2
Total photographs	8	2	10	4	9	4	3	40
Total individuals	4	2	7	1	5	4	2	25

Although our camera-trapping survey was done in 2013, it provides information valuable for a poorly studied mammal species (Hernández-Sánchez and Santos-Moreno, 2022). Until recently, the study of the Mephitidae species has gained interest, such as aspects of its activity patterns and its coexistence (Farías-González and Hernández-Mendoza, 2021; Hernández-Sánchez and Santos-Moreno, 2022) or interactions (Farías-González and Vega-Flores, 2019).

We found the capture rate of the hooded skunk in the Mixteca (1.62 photographs/100-camera-days) was several times higher than that reported in other regions in Mexico (0.20-0.52 photographs/100-camera-days; Monroy-Vilchis et al. 2011, Aranda et al. 2012, Cortés-Marcial and Briones-Salas 2014, Cruz-Jácome et al. 2015, Charre-Medellín et al. 2016, Pérez-Irineo et al. 2020). In most camera-trap studies cited, the surveys were performed in various land covers, from dry forests to mountain cloud and pine-oak forests (Monroy-Vilchis et al. 2011, Aranda et al. 2012, Cortés-Marcial and Briones-Salas 2014, Cruz-Jácome et al. 2015), such vegetation covers are scarcely associated to the hooded skunk. Then, the higher capture rate in the locality of the Mixteca could show the preference of the hooded skunk for open habitats and pasturelands (List and MacDonald 1998, Cervantes et al. 2002, Lorenzo et al. 2005).

Notably, we found skunks shared sites, up to five different individuals in the same camera-trap station per season. Stations recording only one individual were rare. Studies in a peri-urban environment reported males of the hooded skunk were territorials, with no overlapping in their home range, but they overlapped with the female home ranges (Mora et al. 2010). However, intraspecific tolerance was found in the striped skunk, which overlapped between 10 % and 56 % of their home range in natural habitats (Hansen 1997, Neiswenter 2004). In the Mixteca region, skunks shared sites along the study and within seasons, also suggesting an intraspecific tolerance behavior. We did not recognize the sex for most of the individuals; consequently, two possibilities should be explored: skunks in the same site correspond to a male and several females, or there is

Table 2. Parameters of abundance of the hooded skunk (Mephitis macroura) by season in the Mixteca region, Oaxaca, Mexico.

Season (Model)	N	Capture rate	Ind	Recaptures	AICc	Abundance (SE)	LCI	UCI	Z test closure	p value
Dry season (*M0*)	12	1.43	8	4	55.54	12.60 (4.77)	8.85	32.61	-0.52	0.303
Pre-rainy season (*M0*)	22	2.62	12	9	76.07	21.10 (7.43)	14.24	48.95	-2.10	0.018
Rainy season (*M0*)	8	0.95	7	1	40.24	20.20 (15.83)	9.08	90.97	-1.00	0.159

N= number of independent events; capture rate= number of events and effort of survey per 100, Ind= different individuals identified, AICc= Akaike Information Criteria corrected, Abundance estimated (SE)= error standard of abundance estimated; LCI and UCI= lower and upper confidence intervals at 95 %.

a male-male tolerance facilitated by the availability of resources, as suggested for the striped skunk (Hansen 1997).

The abundance estimated for the hooded skunk in the Mixteca region was lower but within the range reported previously in grasslands, marshes, and scrubs of the coastal Oaxaca (0.0-9.0 individuals/km^2; Cervantes et al. 2002, Lorenzo et al. 2005), and grasslands, scrub, and riparian areas of southeastern Arizona (1.3-3.9 individuals/km^2; Hass 2003). Concerning seasons, we found the abundance estimated was higher in both the pre-rainy and rainy seasons than in the dry season, contrary to our expectations. In one previous study, Lorenzo et al. (2005) found higher density occurring in the dry season, but Cervantes et al. (2002) found higher density in the rainy season. A higher abundance in the rainy seasons found by Cervantes et al. (2002) akin here could be related to the recruitment of new individuals seeking partners and the success of the mating seasons (February to April; Hoffmeister 1986), allowing the addition of individuals to the population in these seasons.

For capture-recapture studies using camera traps, it has been recommended to deploy many devices covering a large area encompassing the home range of several individuals of the targeted species (Tobler and Powell 2013). Although our study area was large and the distance among camera traps was appropriate, considering the mesocarnivores' home range, including the mean home range of the hooded skunk (2.8-5.0 km; Ceballos and Miranda 1986), the number of camera-trap stations was low. Consequently, we did not obtain spatial capture-recaptures. The abundance underestimation is an artifact that occurs in many methods, and the identification of individuals by pelage is not an exception causing uncertainty. Future studies should be considering many camera traps covering similar areas and shorter space among camera traps. Also, further surveys across the range of the hooded skunk are necessary to understand which factors could affect their populational dynamics.

With this contribution, we show the feasibility of applying camera trapping techniques and capture-recapture models in species of medium sizes, such as skunks, by using their physical characteristics. Studies involving marked animals with tags and camera-trapping will provide support for the approach proposed here. This study shows one of the first population data for the hooded skunk throughout its range. We also found remarkable changes in the composition of individuals between seasons, probably because of recruitment due to mating for the reproductive season.

AUTHORS´CONTRIBUTIONS

Miguel Briones-Salas: conceptualization, investigation, supervision, review and editing. Dagoberto Ramos-Méndez: investigation, field work, methodology, writing early versions. Mario C. Lavariega: conceptualization, investigation, data analysis, writing, review, and editing. Alina Gabriela Monroy-Gamboa: investigation, writing, review, and editing.

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