Mastozoología Neotropical, 29(2):e0681, Mendoza, 2022
Versión on-line ISSN 1666-0536
https://doi.org/10.31687/saremMN.22.29.2.04.e0742

Copyright © SAREM, 2022
http://www.sarem.org.ar
http://www.sbmz.org

Article

LINEAR CAMERA TRAPPING DESIGN FOR JAGUAR POPULATION SURVEYS IN THE LARGEST FOREST REMNANT OF THE PARAGUAYAN CHACO

Laura Villalba[1,2], Leonardo Maffei[2] & María Belén Ortiz[1,2]

[1]Wildlife Conservation Society, Paraguay. [Correspondence: Laura Villalba<lvillalba@wcs.org>].
[2]Jaguar Conservation Program, WCS Paraguay.

ABSTRACT. The jaguar (*Panthera onca*) is of great concern throughout its entire range due to the decline of its populations and the loss of its natural habitats, which is why protected areas, like the Defensores del Chaco National Park in Paraguay, play such an important role in the conservation of this feline. However, the dense vegetation of the Chacoan dry forest can make it difficult to conduct studies beyond existing road networks to learn about wild populations. In this study, we propose a method for calculating jaguar density estimations based on a linear distribution of camera trap stations, considering the limitations of this approach given the standard assumptions of capture-recapture models. We obtained an initial density estimate of 1.14 (0.35-3.8) jaguars/100 km², in addition to recording 14 potential jaguar prey species; of which, *Dolichotis salinicola, Sylvilagus brasiliensis*, and *Mazama gouazoubira* were the most abundant.

RESUMEN. DISEÑO LINEAL PARA ESTUDIOS POBLACIONALES DEL JAGUAR. El jaguar o yaguareté (*Panthera onca*) es motivo de preocupación en su área de distribución debido a la disminución de sus poblaciones y a la pérdida de sus hábitats naturales; por ello, las áreas protegidas, como el Parque Nacional Defensores del Chaco en Paraguay, cumplen un papel preponderante en la conservación de estos felinos. Sin embargo, la poca accesibilidad al bosque seco chaqueño dificulta los estudios fuera de los caminos ya establecidos para conocer las poblaciones silvestres. En este estudio proponemos una metodología para la estimación de la densidad de los jaguares basada en una distribución lineal de las estaciones de trampas cámara, siendo conscientes de las limitaciones que tiene este tipo de distribución y considerando los supuestos de los modelos de captura y recaptura. Obtuvimos una densidad inicial estimada de 1.14 (0.35-3.8) individuos/100 km², además de registrar 14 especies presa potenciales del jaguar, entre las cuales *Dolichotis salinicola, Sylvilagus brasiliensis* y *Mazama gouazoubira* son las más abundantes.

Key words: *Panthera onca*, Gran Chaco, camera traps, relative density, Defensores del Chaco National Park.

Palabras clave: *Panthera onca*, Gran Chaco, trampas cámara, densidad relativa, Parque Nacional Defensores del Chaco.

Cite as: Villalba, L., L. Maffei & M. B. Ortiz. 2022. Linear camera trapping design for jaguar population surveys in the largest forest remnant of the Paraguayan Chaco. Mastozoología Neotropical, 29(2):e0742. https://doi.org/10.31687/saremMN.22.29.2.04.e0742

Recibido 18 febrero 2022. Aceptado 28 julio 2022. Editor asociado: Dr. Thomas E. Lacher

INTRODUCTION

The Gran Chaco is the second largest biome in South America and the largest dry forest biome in the world, covering about 1,000,000 km², of which 25% (250,900 km²) is located in Paraguay (Arnold & Brown 2018). Conservation of tropical dry forests is considered a priority because they are fragile and vulnerable to anthropogenic impacts (crops, livestock, fires), and are home to unique organisms adapted to water stress conditions (Gross et al. 2016), as well as a number of endangered species, including the jaguar, the continent's largest feline. In Paraguay, the jaguar has been the subject of several studies, such as those referring to diet (Taber et al. 1997), genetics and conservation (Giordano 2015), and movements of the species (McBride & Thompson 2018); yet, there is a gap in the knowledge regarding the population status of the species.

The largest jaguar populations in Paraguay are located in the Gran Chaco biome (SEAM et al. 2016), which represents 60% of the entire country. In this region, 14 protected areas have been created under the public domain, the largest of which is the Defensores del Chaco National Park (FMB et al. 2016). This park represents the largest continuous forest block in the western region of Paraguayan Chaco and is covered by dry forest, with a low canopy and dense and tangled vegetation. As a result, surveys in this area are difficult to carry out beyond existing roads, unless the project staff opens new trails, which requires several months of preliminary work and a significant economic investment. This study aims to test a jaguar density estimation based on a linear camera trap design in Defensores del Chaco National Park, while also providing data on the abundance of their potential prey species.

MATERIALS AND METHODS

Study area

The Defensores del Chaco National Park (hereafter Defensores) is located in northwestern Paraguay (**Fig**. 1) and consists of a continuous and homogeneous forest cover, predominantly of Chaco dry forest (FMB et al. 2016), with a semi-arid tropical climate and a dry season that can last 8 months. Rainfall ranges from 500 to 800 mm per year, and although the temperature is typically mild in winter, it can drop to 0°C, while in summer it can rise to 42 °C (FMB et al. 2016). The park is under heavy anthropogenic pressure (illegal roads and poachers) and is surrounded by roads used by large vehicles, such as trucks transporting cattle and charcoal.

Methodology

As a result of the dense and tangled condition of the Chacoan Dry Forest, we had no trails available to penetrate the woods at Lagerenza (the main survey area in the northwestern area of Defensores), except for the three internal roads (see **Fig**. 1). Because camera traps were going to be set up in a linear design along roads, rather than a polygon grid, we calibrated this design by analyzing data from two survey areas in Kaa Iya National Park, Bolivia, where camera traps were set up along both the main truck road and recently opened trails (Maffei et al. 2004; Noss et al. 2012). Using the well-studied data from Kaa Iya, we first analyzed data from all camera traps, and then only the camera traps placed along the road and obtained densities of 1.8 ± 1.2 and 0.5 ± 0.3, respectively, in one survey area and 1.4 ± 1.3 (all CT) and 0.5 ± 0.32 (road only) in the second survey area at Kaa Iya. Regardless of the differences between the two surveys, we found that the estimated density along the road alone was lower than the estimated density in the entire survey area, which means that by applying this methodology of surveying only along linear roads in Defensores, we would be at least, falling on the conservative side of the estimations.

We used standard camera trapping procedures for jaguars (Silver 2004). Camera trap stations were placed in pairs on either side of the road to photograph both sides of the jaguars, due they have asymmetric coat patterns, and they were located at an average distance of 3000 m (range: 940-5900 m) between stations to cover as large an area as possible and to photograph the greatest number of jaguars (Martins et al. 2007). Lagerenza was the main site of survey (with 24 camera trap stations covering 75.2 linear kilometers), with two other complementary sites: Cerro León in the southern part of the park (with 10 camera trap stations covering 22.9 linear kilometers), and Línea 13 in the eastern part of the park (with 11 camera trap stations covering 35 linear kilometers) (see **Fig**. 1).

For density estimation, jaguar individuals were identified based on their spot pattern, which is unique to each individual, and these were recorded in a data matrix from which a capture history was created to obtain an approximation of abundance (Otis et al. 1978). As an initial estimate of density, we estimated the survey area using the mean maximum distance moved (MMDM) as a buffer of the camera traps (Karanth 1995; Soisalo & Cavalcanti 2006) and directly used the number of individuals identified. Following this estimation, and as a comparison parameter, we applied spatially explicit capture-recapture models (SECR), which fit a maximum likelihood integrating models to describe the distribution of animals (activity centers or action area centers) in the area, including the distribution of camera traps and the temporal distance between captures (Borchers & Efford 2008). Considering that camera traps were installed along linear roads, the capture rate of jaguars per kilometer of effort was estimated for the three sites. In addition, all potential prey species for jaguars were recorded and their capture frequency per 1000 traps/night was estimated to standardize records according to sampling effort (Maffei et al. 2002).

RESULTS

Despite having paired cameras at each station, they did not work simultaneously, so the jaguar record-

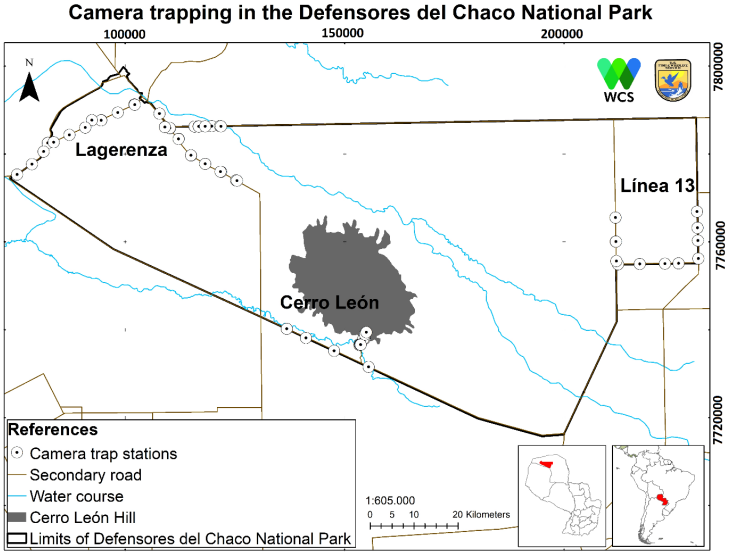

Fig. 1. Location of camera traps at Defensores.

ings were mostly obtained only on one side, either left or right, consequently, the results will be presented according to each side of the identified individuals. At Lagerenza, 19 records were obtained from the right side, corresponding to six individuals, and 18 records were obtained from the left side, corresponding to nine individuals (**Table** 1). The average distance traveled by animals recorded at two or more different stations was 3370 ± 2000 meters. We considered this distance as the MMDM, resulting in a survey area of 493 km². For the six individuals identified on the right side, we estimated a density of 1.2 individuals/100 km². For the nine jaguars identified by the left side, we estimated a density of 1.8 individuals/100 km². Using the SECR model, we estimated a density of 1.4 ± 0.76 individuals/100 km² (CI = 0.55-3.8, left flank) and 0.88 ± 0.44 individuals/100 km² (CI = 0.35-2.2, right flank) with an average of 1.14 individuals/100 km² (CI = 0.35-3.8).

In the other two secondary survey areas, seven and five individuals were recorded from the right and left sides on Cerro León, respectively, while five individuals were recorded from both the left and right sides on Línea 13. The capture rate per kilometer sampled was estimated for the three survey sites; the rates for Lagerenza were lower than those for the other two survey sites (**Table** 1). Because the capture rate at Lagerenza was lower compared to the other two survey sites, we conclude that the density estimated for this site would be the minimum for the area.

Regarding the mammal records, 24 species were photographed, including four xenarthrans, 11 carnivores (five of which were felines), five ungulates, three rodents, and one lagomorph. The most abundant species were foxes (*Cerdocyon thous* and *Lycalopex gymnocercus*), Chacoan mara (*Dolichotis salinicola*), ocelot (*Leopardus pardalis*), forest rabbit (*Sylvilagus brasiliensis*), and grey brocket deer (*Mazama gouazoubira*) with more than 150 records each (Annex 1).

DISCUSSION

This is the first attempt to estimate jaguar density using a linear camera trap distribution. We are aware of the limitations of this type of design, in particular the fact that the traps do not cover a polygon, one of the main assumptions and accustomed uses of capture-recapture models (CRM), as opposed to a line of traps. Other authors have estimated density using CRM with linear surveys (Utreras et al. 2005; Evangelista & Rosas 2011), but for otters, animals with linear home ranges, as opposed to polygons, such is the case for jaguars. For this study, we consider the density estimated with SECR to be more conservative than using the number of individuals per area. Therefore, we prefer to retain the value of 1.14 individuals/100 km² as the density estimation for the jaguar population of Defensores.

Table 1
Summary of data obtained from camera trap sampling.

DATA	Lagerenza	Cerro León	Línea 13
Sampling effort (trap nights)	1440	600	660
Number of total stations	24 (48 camera traps)	10 (20 camera traps)	11 (22 camera traps)
Distance (km) of roads covered by the stations	75.2	22.9	35
Jaguars identified by the right profile	6	7	5
Jaguars identified by the left profile	9	5	5
Individuals capture rate per lineal sampling (indv/100 km2)	Right: 8 indv Left: 12 indv	Right: 30 indv Left: 28 indv	Right: 14 indv Left: 14 indv

Table 2
Comparison of prey species of the jaguar detected in this study and two publications on diet in the Paraguayan Chaco.

Species	This study[1]	(Taber et al. 1997)[2]	(McBride et al. 2010)[2]
Marsupials			
Didelphis albiventris		7	
Xenarthra			
Myrmecophaga tridactyla	13	2	5
Euphractus sexcinctus	6	1	1
Tolypeutes matacus	38	2	3
Ungulates			
Mazama gouazoubira	183	31	
Tapirus terrestris	148	2	5
Pecari tajacu	47	3	9
Tayassu pecari	3	1	23
Catagonus wagneri	3	2	4
Rodents/Lagomorphs			
Dolichotis salinicola	814	8	
Cavia/Galea	2	9	
Sylvilagus brasiliensis	227	31	

[1]Number of photographic records. [2]Frequency of occurrence in feces.

The density determined in this study (D = 1.14/100 km²) is an estimated 58% higher than the only study available for Defensores; Giordano (2015) estimated a density of 0.72 individuals/100 km² based on a study of DNA extraction from feces since the difference observed could be due to the methodology used, as the capture rate of jaguars with camera traps could be higher than the detection rate of feces or because not all jaguars defecate along the roads. In addition, it should be noted that the extraction of jaguar DNA from feces is often not 100% effective. In nearby Kaa Iya National Park in Bolivia, which has a similar habitat to Defensores, 13 camera trap surveys were carried out (Noss et al. 2012) and reported an average density of 0.93 jaguars/100 km² (range: 0.31-1.82), which is only 18% lower than that found in this study. The presence of jaguars at all three sampling sites, located around the edges of Defensores, indicates that the species is distributed throughout the National Park. The capture rates are higher at the two complementary sites, suggesting that the estimated density at the site with the lowest capture rate (Lagerenza) may be the minimum for the area.

A total of 24 medium/large mammal species were found, most of them with abundant records (Annex 1). Except for the carnivore group (which is not usually preyed upon by jaguars), the remaining groups (xenarthrans, ungulates, and rodents) comprise a good prey assemblage for jaguars. Taber et al. (1997) and McBride et al. (2010), based on fecal analysis studies in the Paraguayan Chaco, reported forest rabbit, brocket deer, the three species of peccaries in the Chaco, and three species of medium-sized rodents (*Galea, Cavia*, and *Dolichotis*) as the main prey of jaguars; all these species were recorded

on several occasions (**Table** 2). The only abundant species in the diet studies that was rare in this study was *Tayassu pecari*. The absence of this species in its range and in areas without high hunting pressure has already been reported in other studies (Kiltie & Terborgh 1983; Fragoso et al. 2020), so it is not unexpected that it is very rare in this study despite being found within Defensores.

Defensores is part of the Gran Chaco Jaguar Conservation Unit (UCJ), an area with enough habitat and prey to maintain jaguar populations and ensure the long-term survival of the species (Sanderson et al. 2002). We hope that the information provided in this study will lead to greater and sustained conservation efforts for the Defensores del Chaco National Park in the face of constant threats and ensure the continued existence of the jaguar and its prey in Paraguay's largest protected area.

ACKNOWLEDGMENTS

María del Carmen Fleytas reviewed and edited the article, and provided support while the fieldwork was being conducted; John Polisar supported the project from the beginning; Ángel Brusquetti led the team crews in the field. Technicians from the Ministry of Environment and Sustainable Development (MADES): Iván Marecos, Sara Bauer, Francisco Delgado, and Eliodoro León accompanied the fieldwork, and supported the placement, conditioning, and monitoring of camera traps. Technicians from the Faculty of Exact and Natural Sciences of the Universidad Nacional de Asunción: Yolanda Ramos, Karen Chávez, Patricia Salinas, and Estefanía Valiente accompanied the fieldwork, and reviewed the field records. Fátima Mereles supported the schematic construction of this publication. We also thank the U.S. Fish and Wildlife Service (USFWS) for providing funds to support this research and for the continuous support to WCS in implementing actions for jaguar conservation in the Paraguayan Chaco.

LITERATURE CITED

Arnold, I., & A. Brown. 2018. Evaluación del Gran Chaco Americano. Tarija, Bolivia. https://es.scribd.com/document/477210499/Evaluacion-Ecorregional-NATIVA-1-pdf

Borchers, D. L., & M. G. Efford. 2008. Spatially explicit maximum likelihood methods for capture-recapture studies. Biometrics 64:377-385. https://doi.org/10.1111/j.1541-0420.2007.00927.x

Evangelista, E., & F. C. Rosas. 2011. The home range and movements of giant otters (*Pteronura brasiliensis*) in the Xixuaú Reserve, Roraima, Brazil. IUCN Otter Spec. Group Bull. 28(A):31-37. http://www.otterspecialistgroup.org/Bulletin/Volume28A/Evangelista_Rosas_2011a.htm.

FMB, Gef, Undp, Seam. 2016. Management Plan for the Defensores del Chaco National Park. Period 2017-2027. Secretaria del Ambiente/Fundación Moisés Bertoni. Asunción, Paraguay.

Fragoso, J. M. V. et al. 2020. Mysterious disappearances of a large mammal in Neotropical forests. BioRxiv 2020.12.08.416552; https://doi.org/10.1101/2020.12.08.416552.

Giordano, A. J. 2015. Status, Conservation, and Population Genetics of the Jaguar (*Panthera onca*) in Paraguay and the Dry Gran Chaco. PhD. Thesis Texas Tech University. https://ttu-ir.tdl.org/handle/2346/62350.

Gross, J. E., S. Woodley, L. A. Welling, & E. M. Watson (eds.). 2016. Adapting to climate change: guidance for protected area managers and planners. Best Practice Protected Area Guidelines Series N° 24, Gland, Switzerland. 152 pp. https://portals.iucn.org/library/sites/library/files/documents/PAG-024.pdf https://doi.org/10.2305/iucn.ch.2017.pag.24.en

Karanth, K. U. 1995. Estimating tiger *Panthera tigris* populations from camera-trap data using capture-recapture models. Biol Conserv 71:333-336. https://doi.org/10.1016/0006-3207(94)00057-w

Kiltie, R. A., & J. Terborgh. 1983. Observations on the behavior of rain forest peccaries in Peru: Why do white-lipped peccaries form herds? Zeitschrift für Tierpsychologie. 62:241-255. https://doi.org/10.1111/j.1439-0310.1983.tb02154.x

Maffei, L., E. Cuéllar, & A. J. Noss. 2002. Use of camera-traps for the evaluation of mammals in the Chaco-Chiquitanía ecotone. Bol Ecol 11:55-65.

Maffei, L., E. Cuellar, & A. J. Noss. 2004. One thousand jaguars (*Panthera onca*) in Bolivia's Chaco? Camera trapping in the Kaa-Iya National Park. J Zool Lond 262:295-304. https://doi.org/10.1017/s0952836903004655

Martins, S. D., J. G. Sanderson, & J. D. S. Silva-Júnior. 2007. Monitoring mammals in the Caxiuanã National Forest, Brazil - First results from the Tropical Ecology, Assessment and Monitoring (TEAM) program. Biodivers Conserv 16:857-8. https://doi.org/10.1007/s10531-006-9094-x.

McBride, R. T., A. Giordano, & W. B. Ballard. 2010. Note on Winter diet of jaguars *Panthera onca* in the Paraguayan transitional Chaco. Bellbird 4:1-12.

McBride, R. T., & J. J. Thompson. 2018. Space use and movement of jaguar (*Panthera onca*) in western Paraguay. Mammalia 82. https://doi.org/10.1515/mammalia-2017-0040.

Noss, A. J. et al. 2012. Comparison of density estimation methods for mammal populations with camera traps in the Kaa-Iya del Gran Chaco landscape. Animal Conservation 15:527-535. https://doi.org/10.1111/j.1469-1795.2012.00545.x

Otis, D. L., K. P. Burnham, G. C. White, & D. R. Anderson. 1978. Statistical inference from capture data on closed populations. Wildlife Monographs 62:1-135.

Sanderson, E. W. et al. 2002. Planning to save a species: the jaguar as a model. Conservation Biology 16:58-72. https://doi.org/10.1046/j.1523-1739.2002.00352.x

SEAM, W. C. S., & Itaipu Binacional. 2016. Plan de Manejo de la *Panthera onca*, Paraguay 2017-2027. 1era. edición. Asunción, Paraguay. 90 pp.

Silver, S. 2004. Estimando la abundancia de jaguares mediante trampas-cámara. WCS protocol.

Soisalo, M. K., & S. M. C. Cavalcanti. 2006. Estimating the density of a jaguar population in the Brazilian Pantanal using camera-traps and capture–recapture sampling in combination with GPS radio-telemetry. Biol Cons 129:487-496. https://doi.org/10.1016/j.biocon.2005.11.023

Taber, A. B., A. J. Novaro, N. Neris, & F. Colman. 1997. The food habits of sympatric jaguar and puma in the Paraguayan Chaco. Biotropica 29:204-213. https://doi.org/10.1111/j.1744-7429.1997.tb00025.x

Utreras, B. V., R. E. Suárez, G. Zapata-Ríos, G. Lasso, & L. Pinos. 2005. Dry and rainy season estimations of giant otter *Pteronura brasiliensis*, home range in the Yasuní National Park, Ecuador. LAJAM 4:191-194. https://doi.org/10.5597/lajam00085

Annex 1. List of species recorded.

	Lagerenza		Cerro León		Línea 13		TOTAL	
	Reg.	Freq.	Reg.	Freq.	Reg.	Freq.	Reg.	Freq.
Xenarthra								
Tolypeutes matacus	14	10	1	2	23	35	38	14
Euphractus sexcinctus	5	3			1	2	6	2.2
Priodontes maximus	1	1					1	0.4
Myrmecophaga tridactyla	3	2	5	8	5	8	13	4.8
Carnivores								
Galictis cuja	2	1					2	0.7
Eira barbara	8	6	1	2	1	2	10	3.7
Nasua nasua					27	41	27	10
Procyon cancrivorus	3	2			2	3	5	1.8
Cerdocyon thous	790	549	166	277			956	354
Lycalopex gymnocercus	157	109	14	23	28	42	199	73
Leopardus pardalis	132	92	178	297	40	61	350	129
Leopardus geoffroyi	6	4			3	5	9	3.3
Puma jagouaroundi	1	1	1	2	3	5	5	1.8
Puma concolor	77	53	30	50	27	41	134	49
Panthera onca	52	36	12	20	22	33	86	31.8
Ungulates								
Mazama gouazoubira	78	54	52	87	53	80	183	67.8
Pecari tajacu	11	8	2	3	34	52	47	17.4
Tayassu pecari	3	2					3	1.1
Catagonus wagneri	1	1			2	3	3	1.1
Tapirus terrestris	87	60	13	22	48	73	148	54.8
Rodents								
Cavia aperea			2	3			2	0.7
Dolichotis salinicola	323	224	8	13	483	732	814	301.5
Dasyprocta azarae			1	2			1	0.4
Lagomorphs								
Sylvilagus brasiliensis	141	98	54	90	32	48	227	84.1

Reg.: records, number of photos per species. Freq.: frequency, records per 1000 camera traps night (tn). Lagerenza: 1440 tn; Cerro León: 600 tn; Línea 13: 660 tn.